Resiliency and Vulnerability of Boreal Forest Habitat across DoD Lands of Interior Alaska

SERDP Project: RC18-C2-1183

PI Dr. Scott Goetz, NAU

Presenter: Matt Macander,

ABR, Inc.—Environmental Research & Services

Resiliency and Vulnerability of Boreal Forest Habitat across DoD Lands of Interior Alaska

Project Progress and Results

- *Deep burning shifts forests from spruce to deciduous tree dominance*
- *Climate and insect leaf mining Impacts aspen productivity*
- *Aspen mortality and decreased productivity: drivers and trends*
- *Compiled extensive forest inventory PSP database and early warning signals of tree mortality and biomass change*
- *Advanced mechanistic predictive modeling of forest composition and productivity under climate change scenarios.*

Technology Transition

- *Next steps in the development of the technology and planned outreach efforts to potential end-users is in its nascent stages, but productive meetings have been held and more are scheduled.*

Project Team: Resiliency and Vulnerability of Boreal Forest Habitat across DoD Lands of Interior Alaska

Project Number RC18-C2-1183

Dr. Scott Goetz (PI), Michelle Mack, Adrianna Foster

Northern Arizona University

- Biophysical remote sensing, ecosystem assessment & monitoring
- Arctic and boreal ecology, vegetation succession & post-disturbance recovery
- Ecosystem modeling / individual based tree models

Dr. Brendan Rogers, Stefano Potter, Sol Cooperdock

Woods Hole Research Center

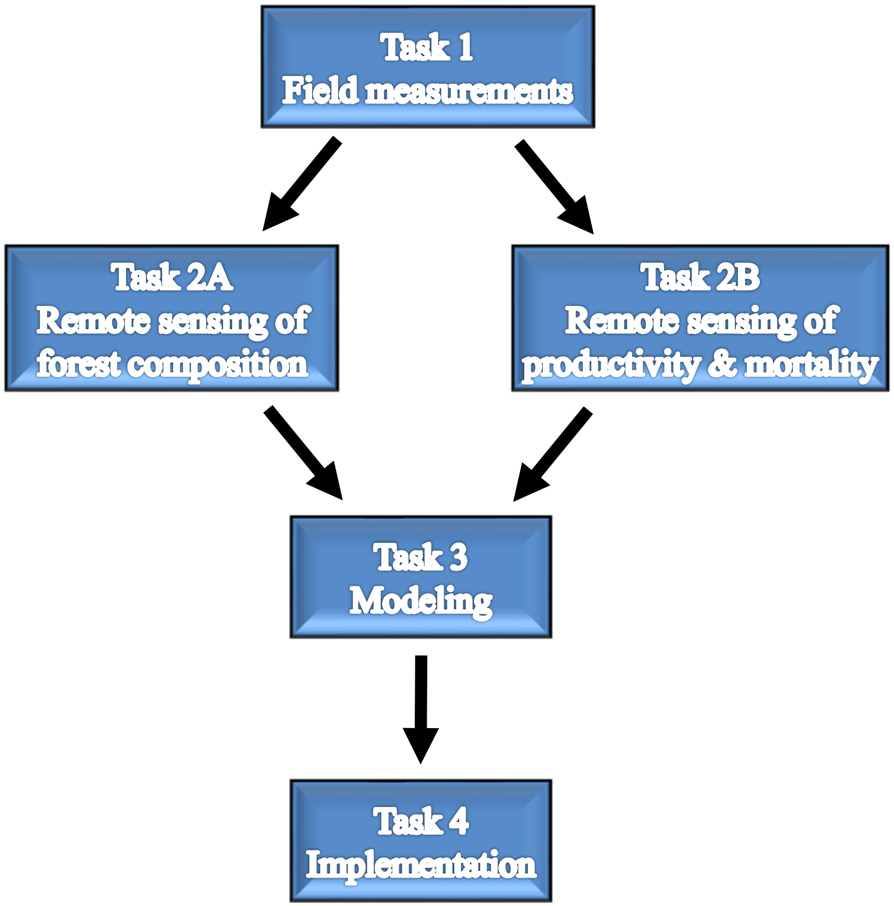
- Remote sensing, vulnerability assessment

Mr. Matt Macander & JJ Frost

ABR, Inc.—Environmental Research & Services

- Vegetation mapping, change detection, geospatial techniques

Technical Approach / Research Objectives



Our technical approach includes 4 primary research tasks, which ultimately flow into implementation.

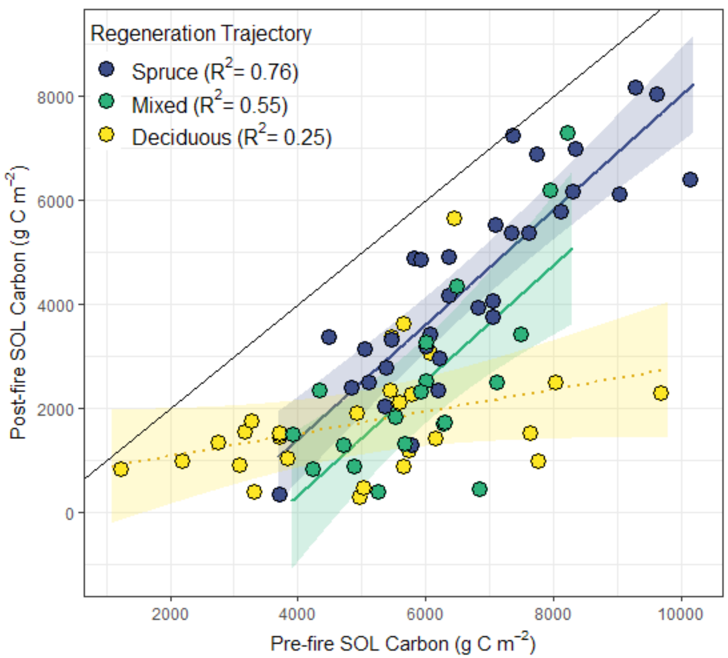
Tasks inform one another

- Field measurements inform remote sensing product development (composition, productivity & mortality).
- Remote sensing products inform the modeling efforts.

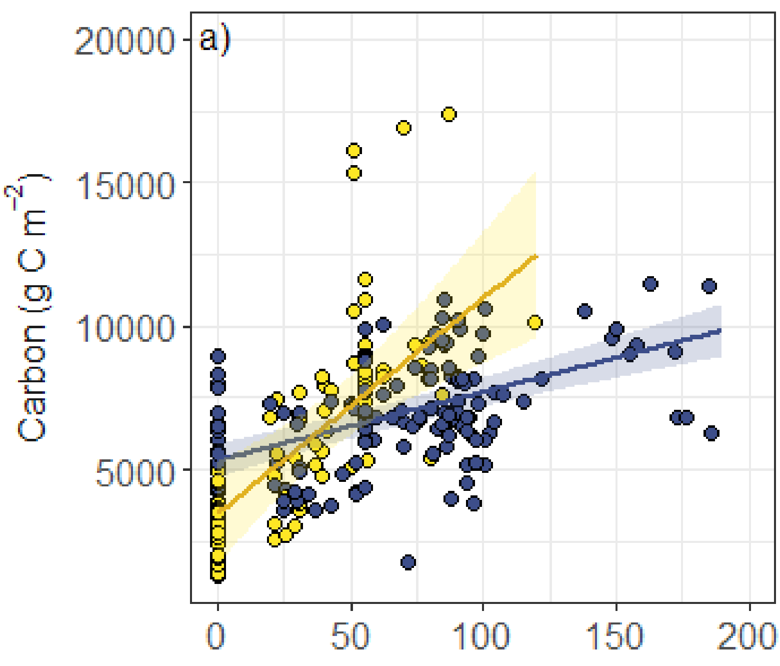
All are relevant to implementation and transitioning outputs & capabilities.

Field Measurement Results

Deep burning shifts forests from spruce to deciduous tree dominance



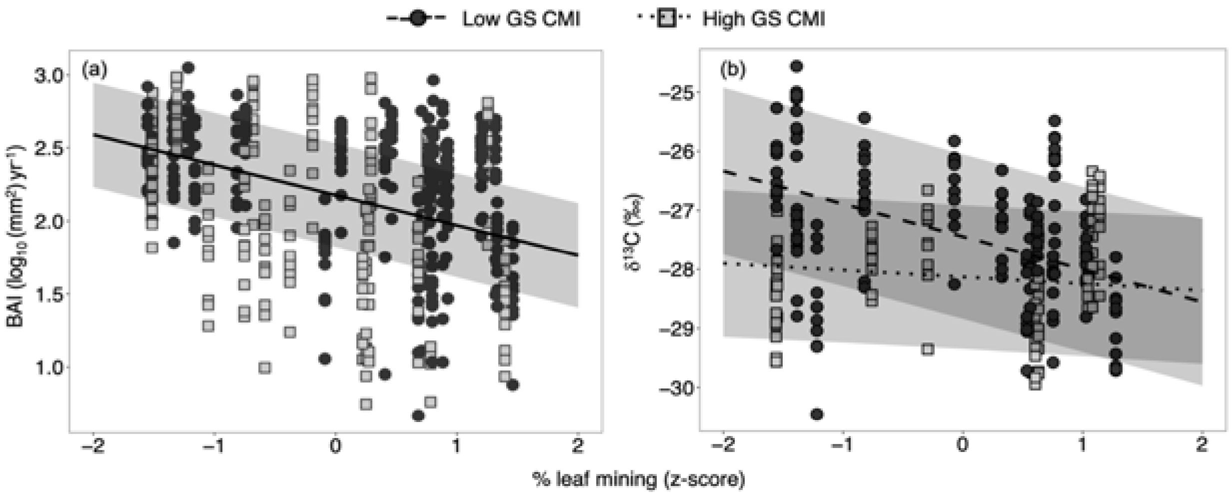
Deep burning of organic soil reduces ecosystem carbon pools and shifts post-fire regeneration to deciduous dominance



Deciduous stands accumulate carbon more rapidly over succession, resulting in a net increase in ecosystem carbon storage despite greater initial combustion losses

Field Measurement Results

Impacts of climate and *Phyllocnistis populiella* leaf mining on aspen productivity and physiology

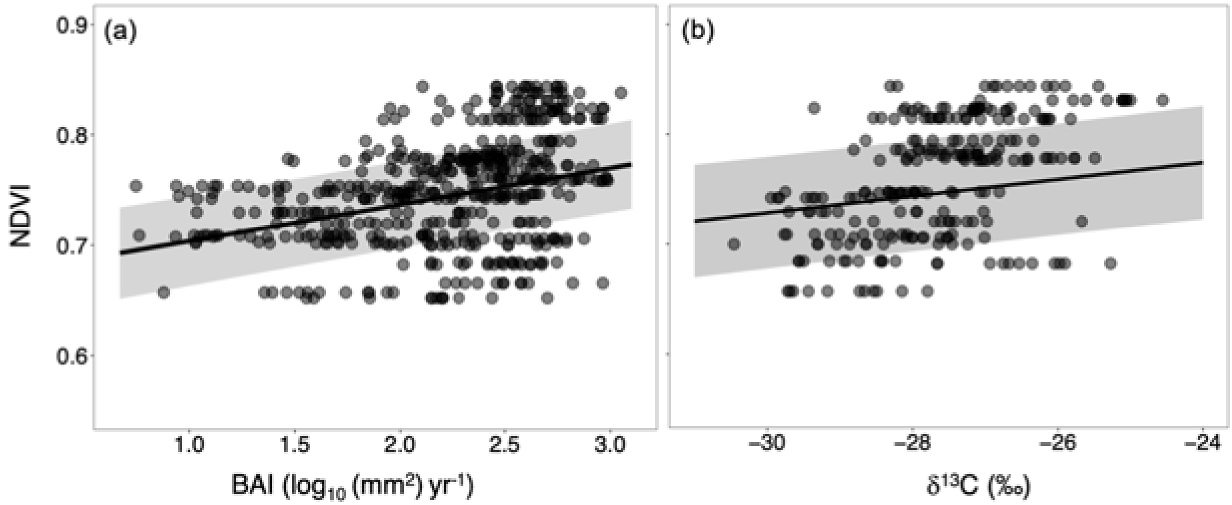


- Productivity (Basal Area Increment) decreased with greater leaf mining, and was not sensitive to growing season moisture
- Climate and leaf mining interacted to influence physiology ($\delta^{13}C$), with greater mining resulting in decreased $\delta^{13}C$ when moisture availability was low

Leaf mining has larger impact on aspen productivity and physiology than climate (thus far)

Results

Relationships between summer NDVI and aspen productivity and physiology



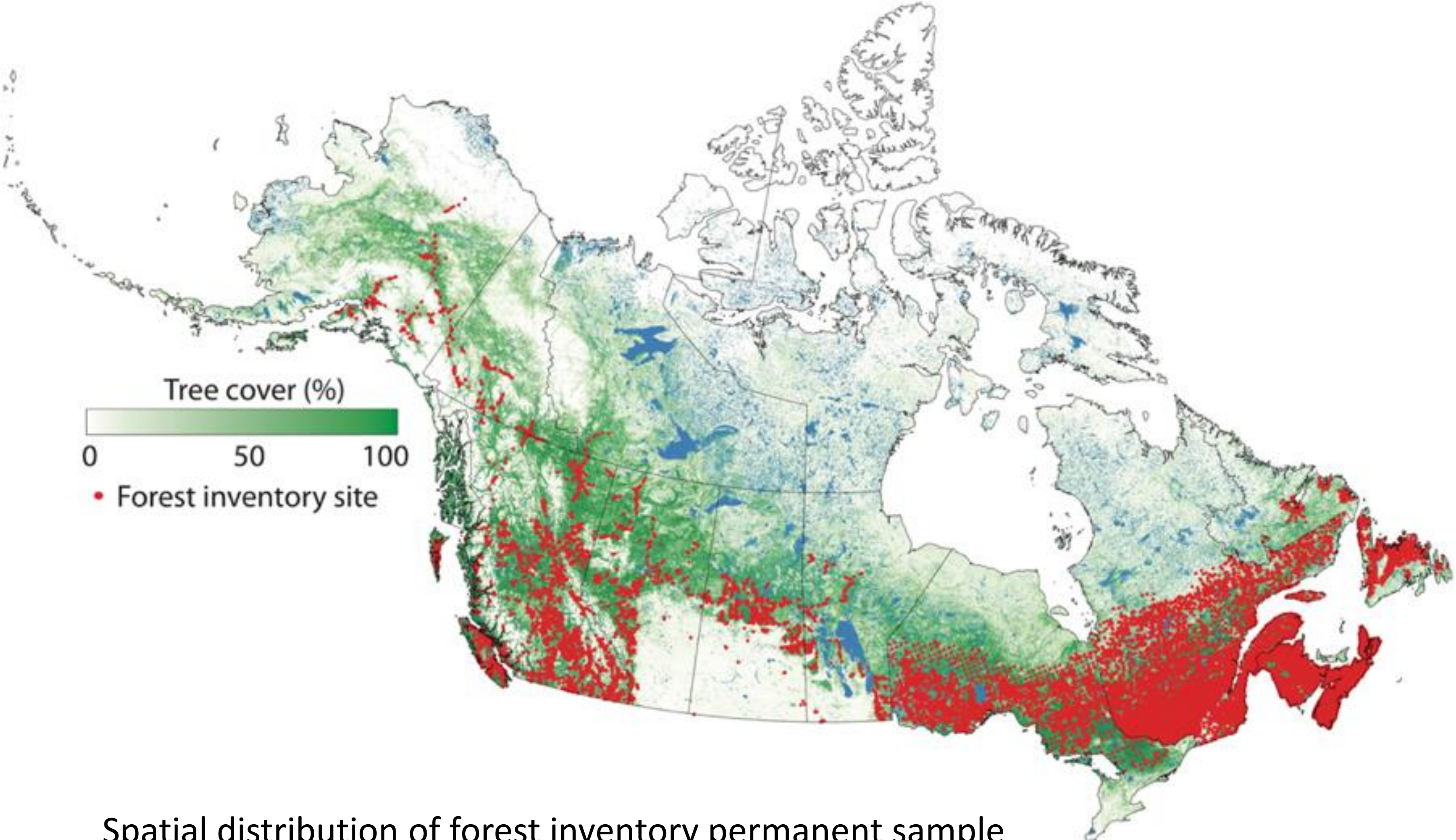
- Mean annual July-August NDVI was positively correlated with BAI and $\delta^{13}C$, capturing the effects of leaf mining on aspen productivity and physiology

It is essential to account for leaf mining when interpreting satellite vegetation productivity trends in interior Alaska

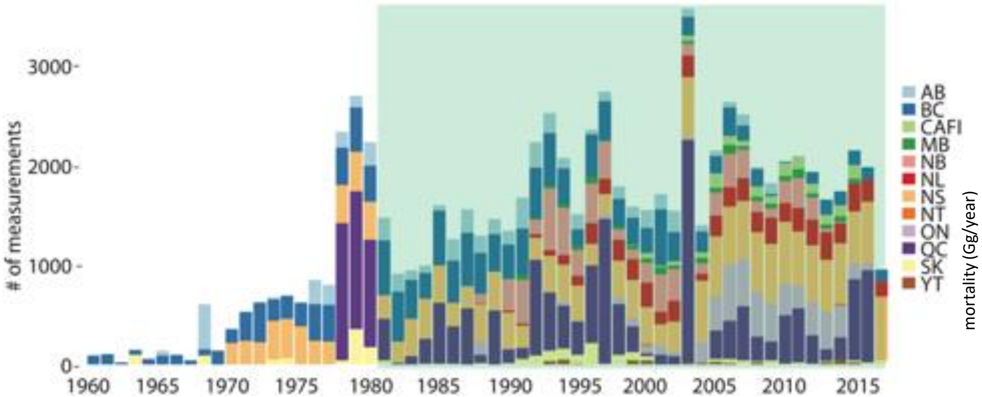
Task 2b: **Remote sensing of productivity & mortality**

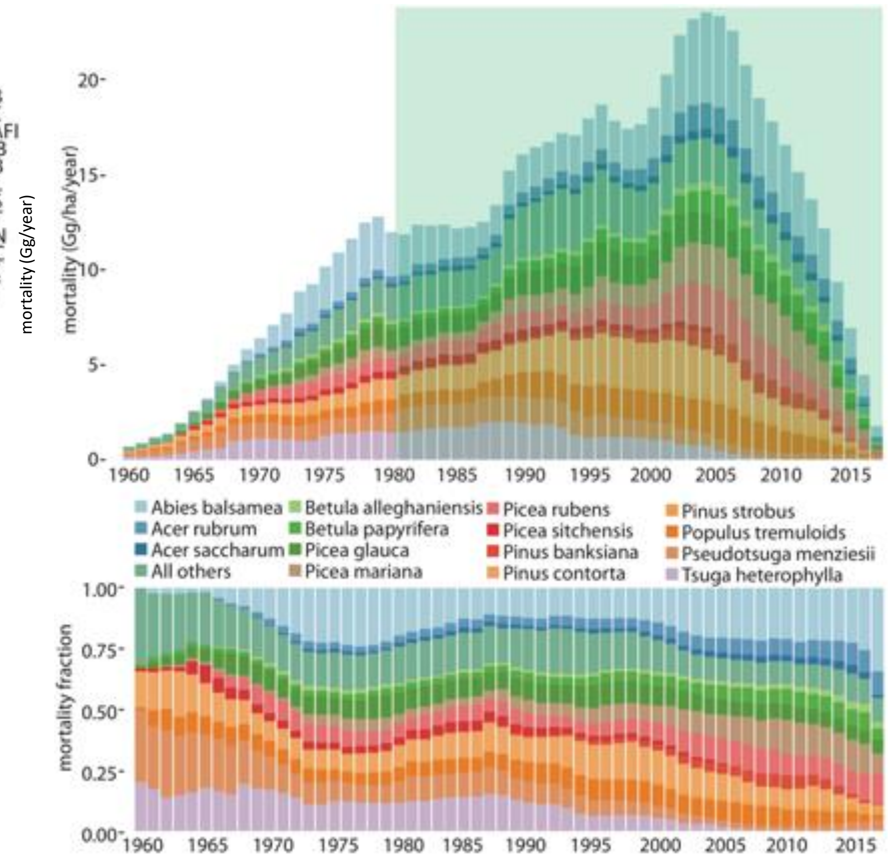
Subtask: Characterization of Early Warning Signals (EWS)

- *Overarching goal*: develop a comprehensive characterization of mortality EWS in western boreal North America.
- Long-term NDVI from Landsat (30 m), MODIS (250 m) and AVHRR (8 km)
- Repeat forest inventories from AK & western Canada
- Apply a variety of EWS metrics to different sensors & inventories
- *Questions*
  1. What combination of EWS metrics, sensors, and mortality calculations are most robust?
  2. How does this vary by region, species, mortality level, canopy density, stand age, landscape position, drought/infestation severity, and inventory specifications?
  3. What is the predictive power of these EWS, and over what timescales?



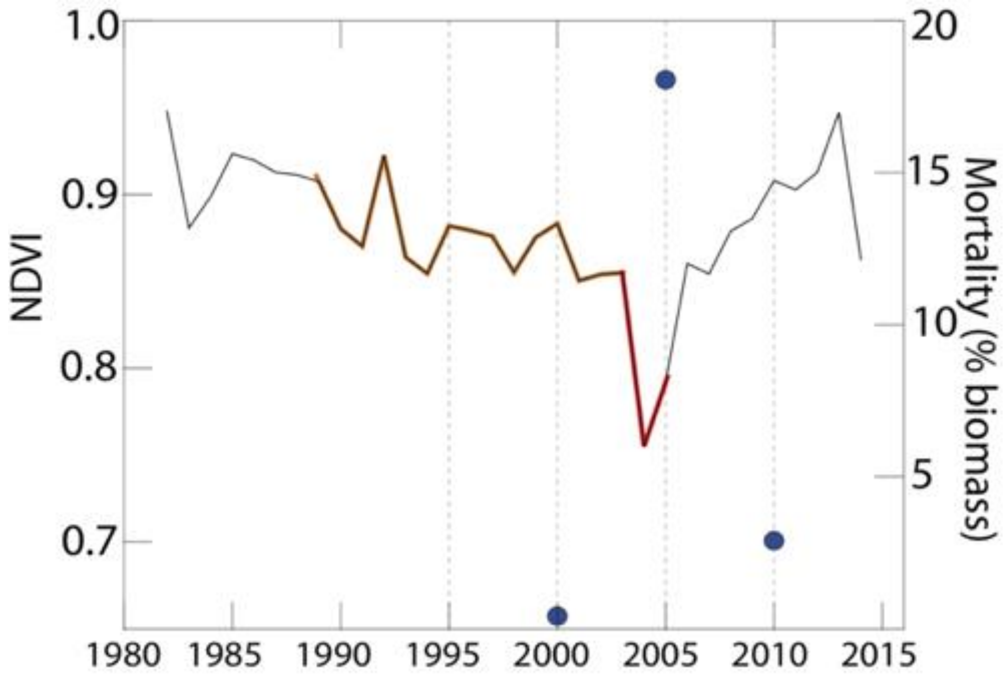
Spatial distribution of forest inventory permanent sample plots (PSPs) across Alaska and Canada. The total number of PSPs is greater than 30,000.

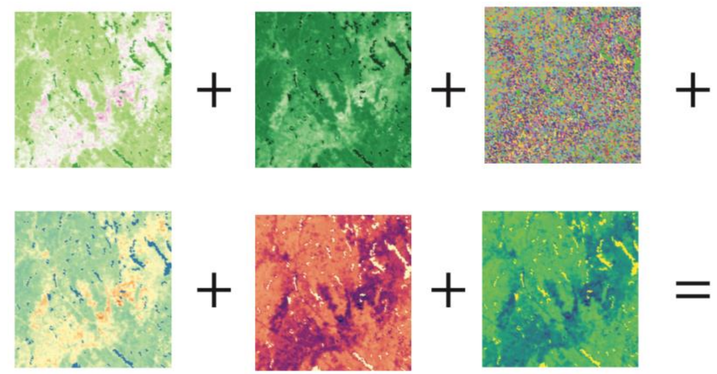




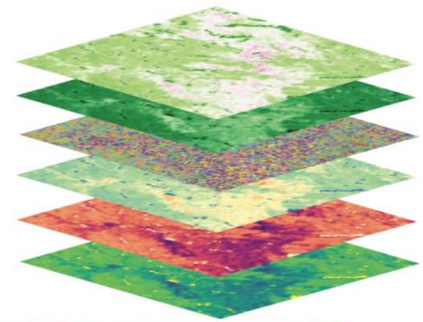
The **top left** panel shows the number of inventory observations each year.
The **right panel** shows the mortality (in both Gg per year and fraction of total) of the 15 most commonly observed tree species.

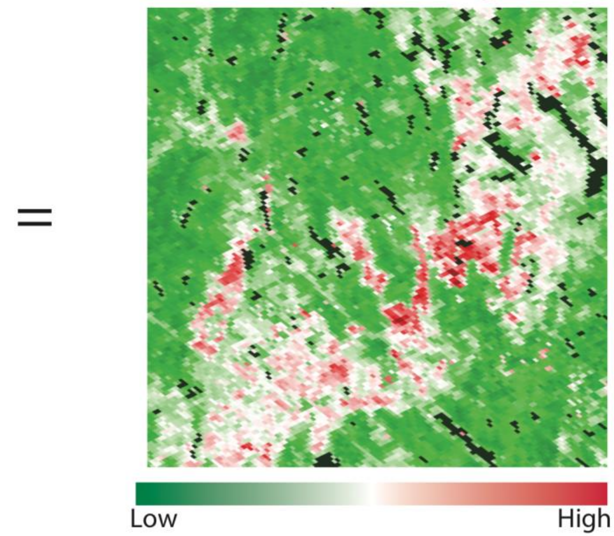
Green shaded boxes represent the satellite era (~1980 to present).





NDVI-derived early warnings metrics will be combined with other influential geospatial predictors to forecast mortality in a statistical modeling framework. Models will then be extrapolated across boreal North America.





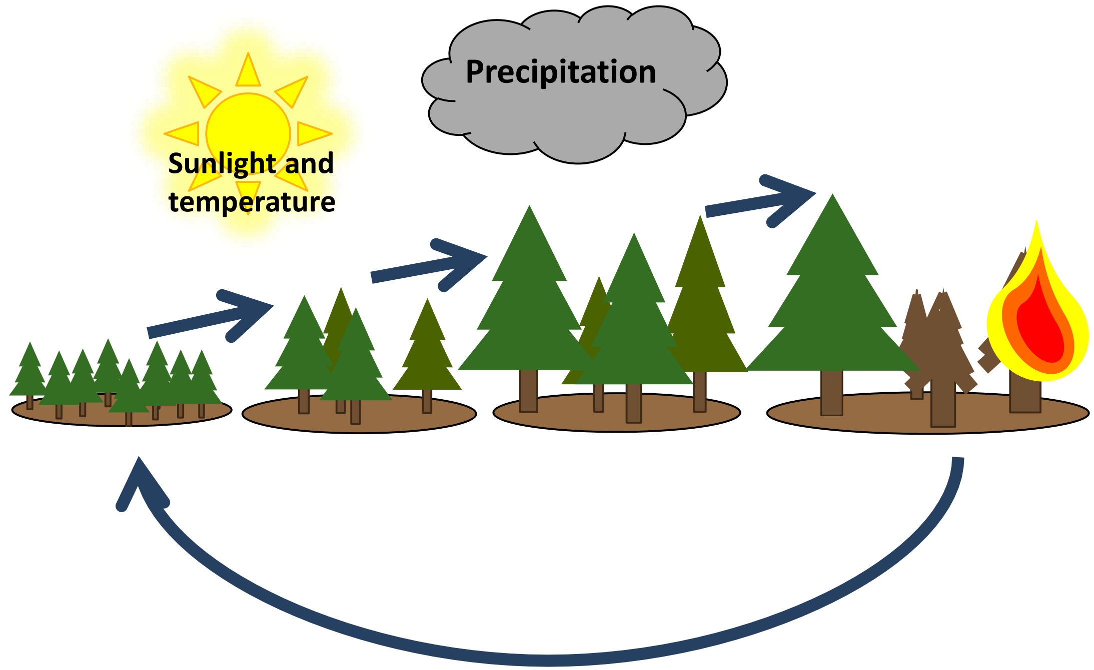
Likelihood of mortality event
(or biomass change)

- Examples of early warning signals of tree mortality that can be detected in satellite NDVI records.
- Above, a PSP’s NDVI (line) decreases for 20+ years preceding a high mortality event (point).
- Right, various statistical metric responses to a variable approaching a critical transition (in this case mortality), or general biomass changes.
- These statistical responses can be applied to satellite NDVI trends to predict transitions/changes.

Task 3: **Predictive modeling**

- Use Tasks 1 & 2 to develop predictive models of forest type, cover, productivity, and mortality for DoD managers and the scientific community
- *Questions*:
  1. What will forest composition and cover of recently burned landscapes look like in 10-50 years?
  2. What areas of the landscape are most vulnerable or resilient to:
     i. fire-driven shifts in forest composition?
     ii. declining productivity?
     iii. drought & pest related mortality?
  3. How do these projected future conditions differ from historic landscapes?

UVAFME – individual tree-based model

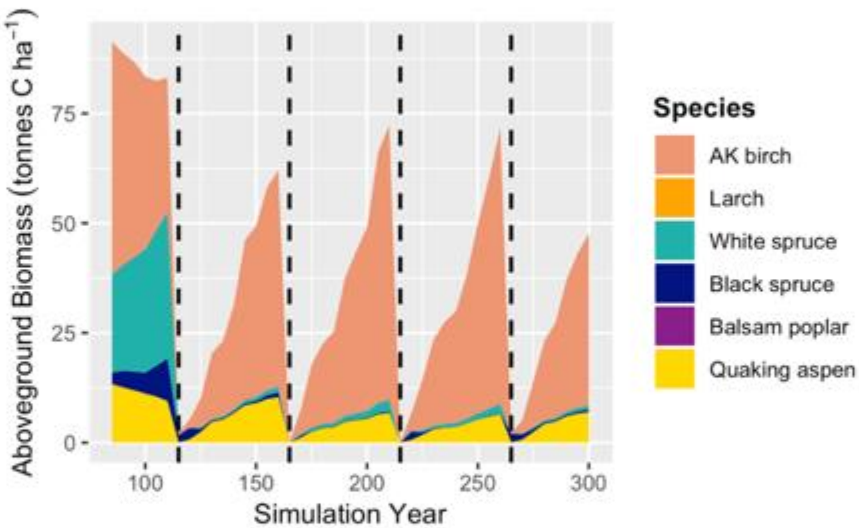


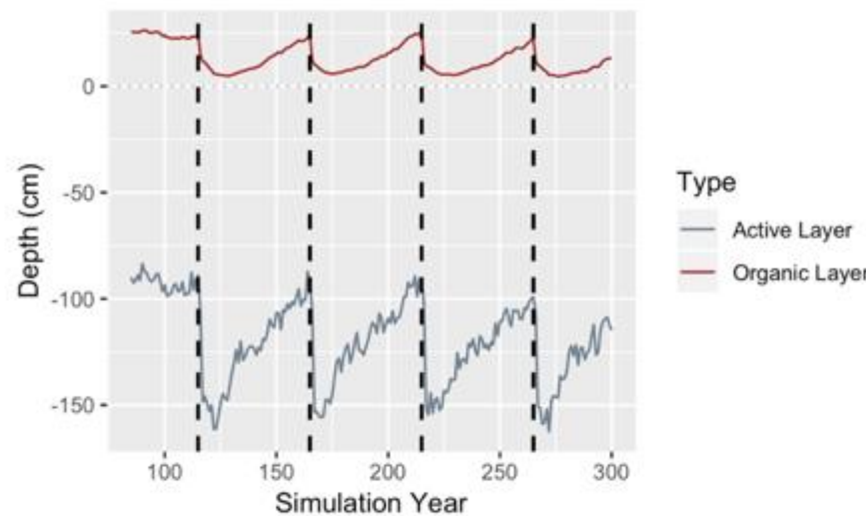
Simulates the regeneration, growth, and mortality of individual trees on patches of a forested landscape

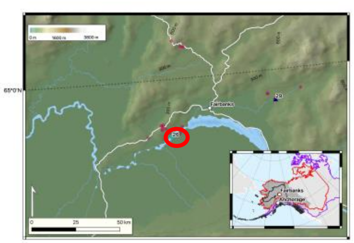
Yan & Shugart 2005

UVAFME is able to capture vegetation-fire-soil interactions

White spruce site - fires recurring every 50 years.







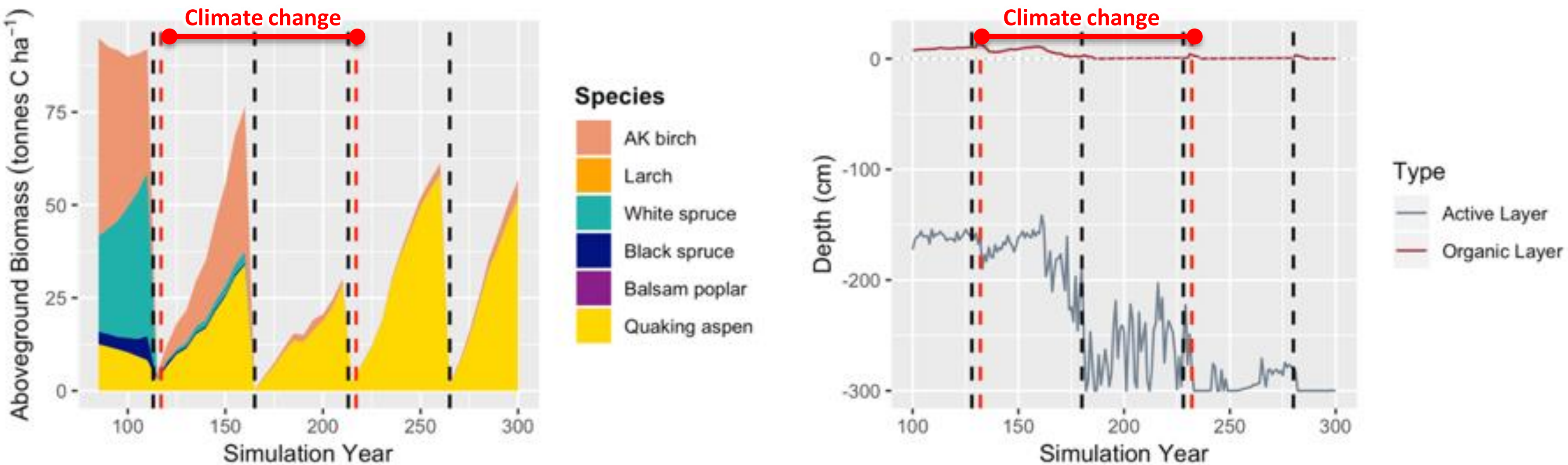
Foster et al., in prep for *ERL*

Fire -> canopy opens up, part of the organic layer is consumed
-> Leads to increased active layer depth
As forest regenerates and organic layer develops, active layer decreases.

Recurring fires shift white spruce forest to birch/aspen

UVAFME is able to capture vegetation-fire-soil interactions

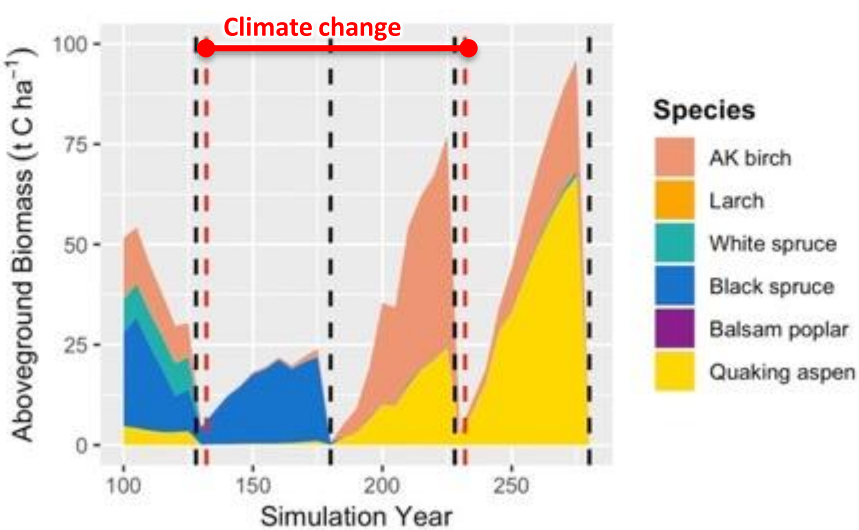
White spruce site - fires recurring every 50 years + concurrent RCP 8.5 climate change

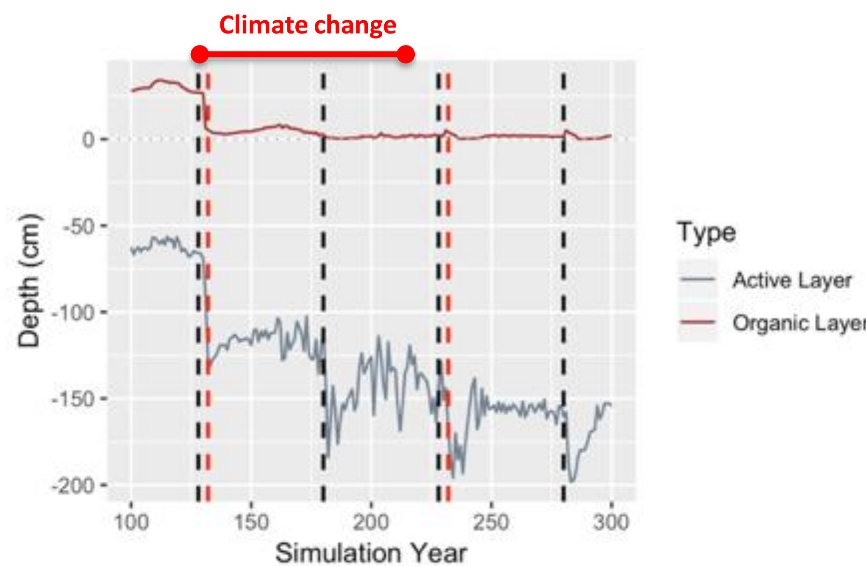


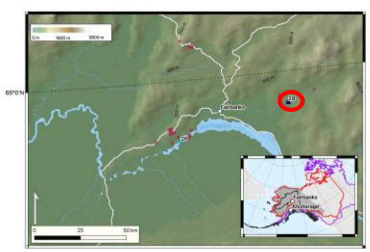
Recurring fires together with climate change, rapidly shift WS site to aspen. Organic layer decreases and active layer increases significantly.

Foster et al., in prep for *ERL*

Black spruce site - fires recurring every 50 years + concurrent RCP 8.5 climate change



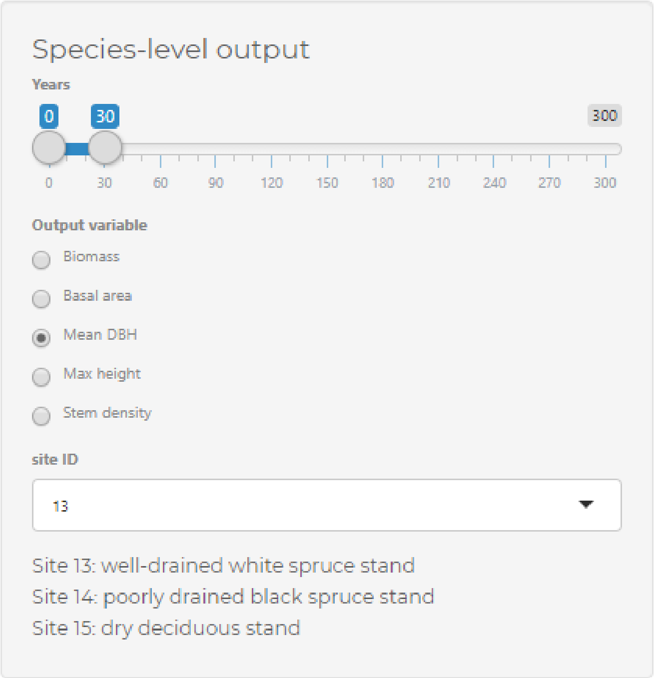


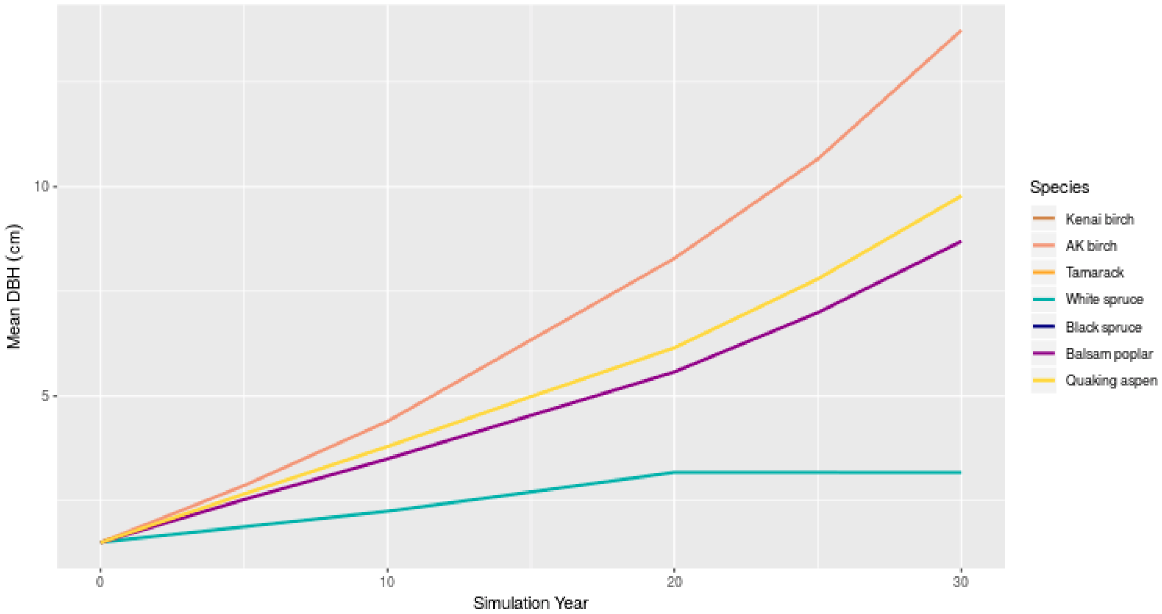


With climate change a 50 year FRI shifts black spruce forest to high productivity aspen stand

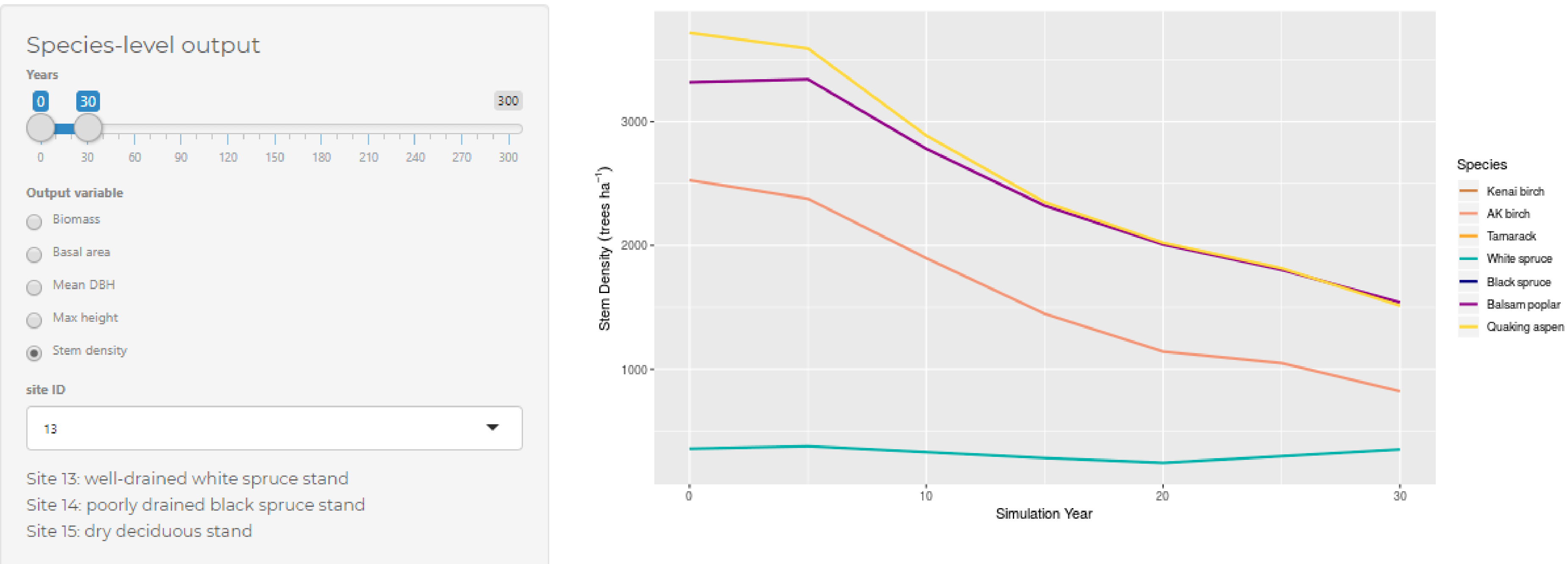
Foster et al., in prep for *ERL*

UVAFME Shiny App (beta)



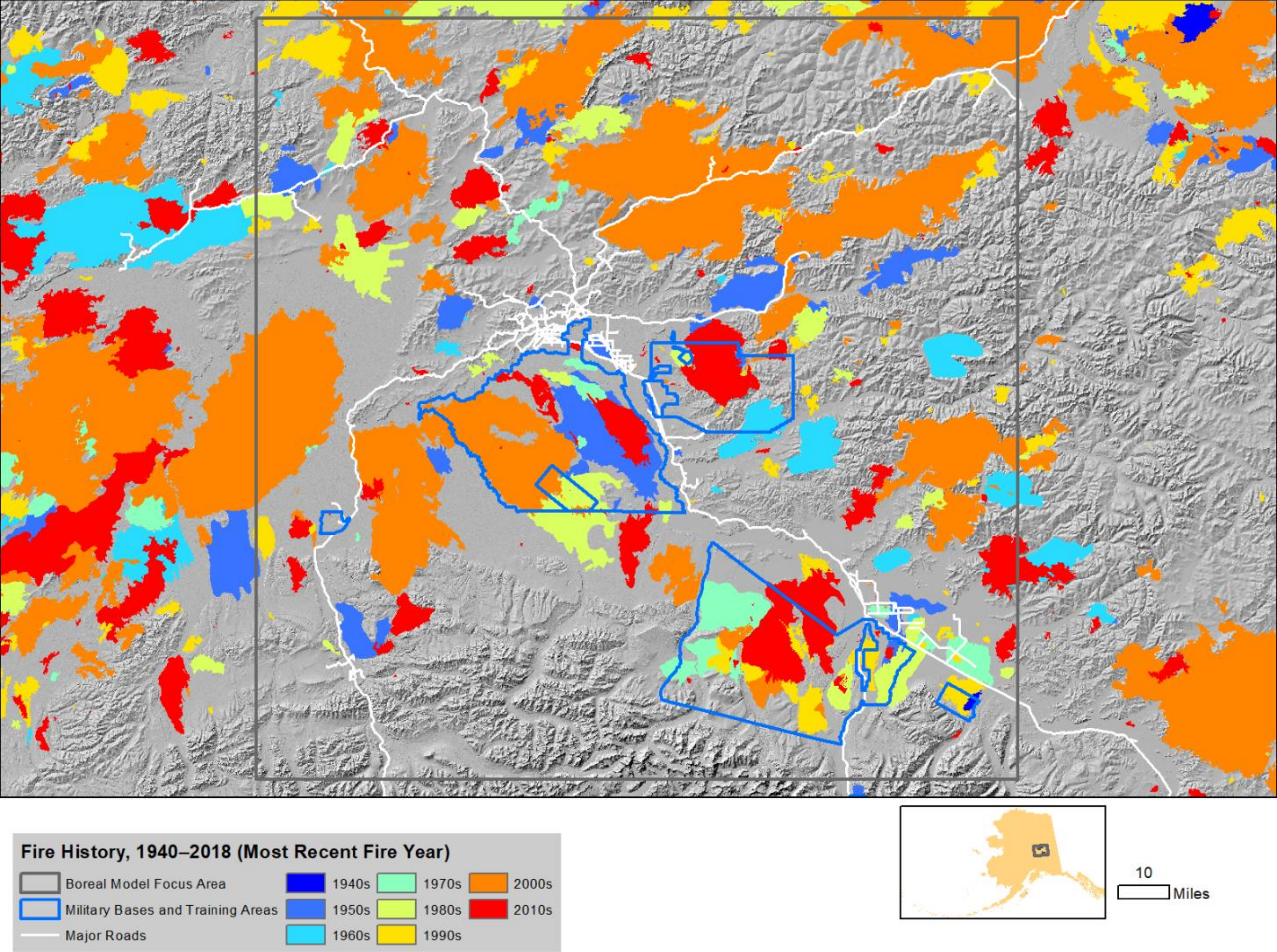


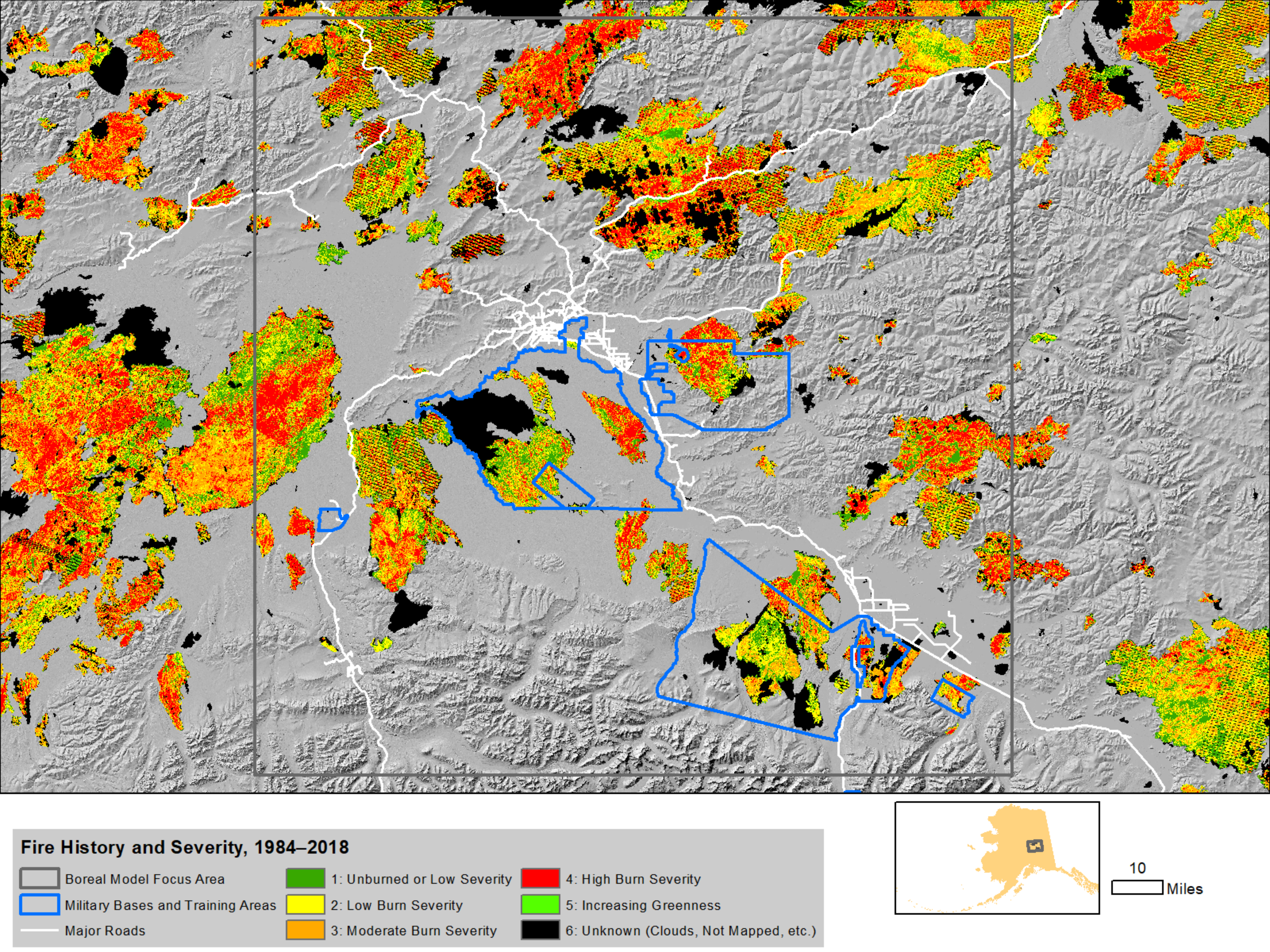
UVAFME Shiny App (beta)

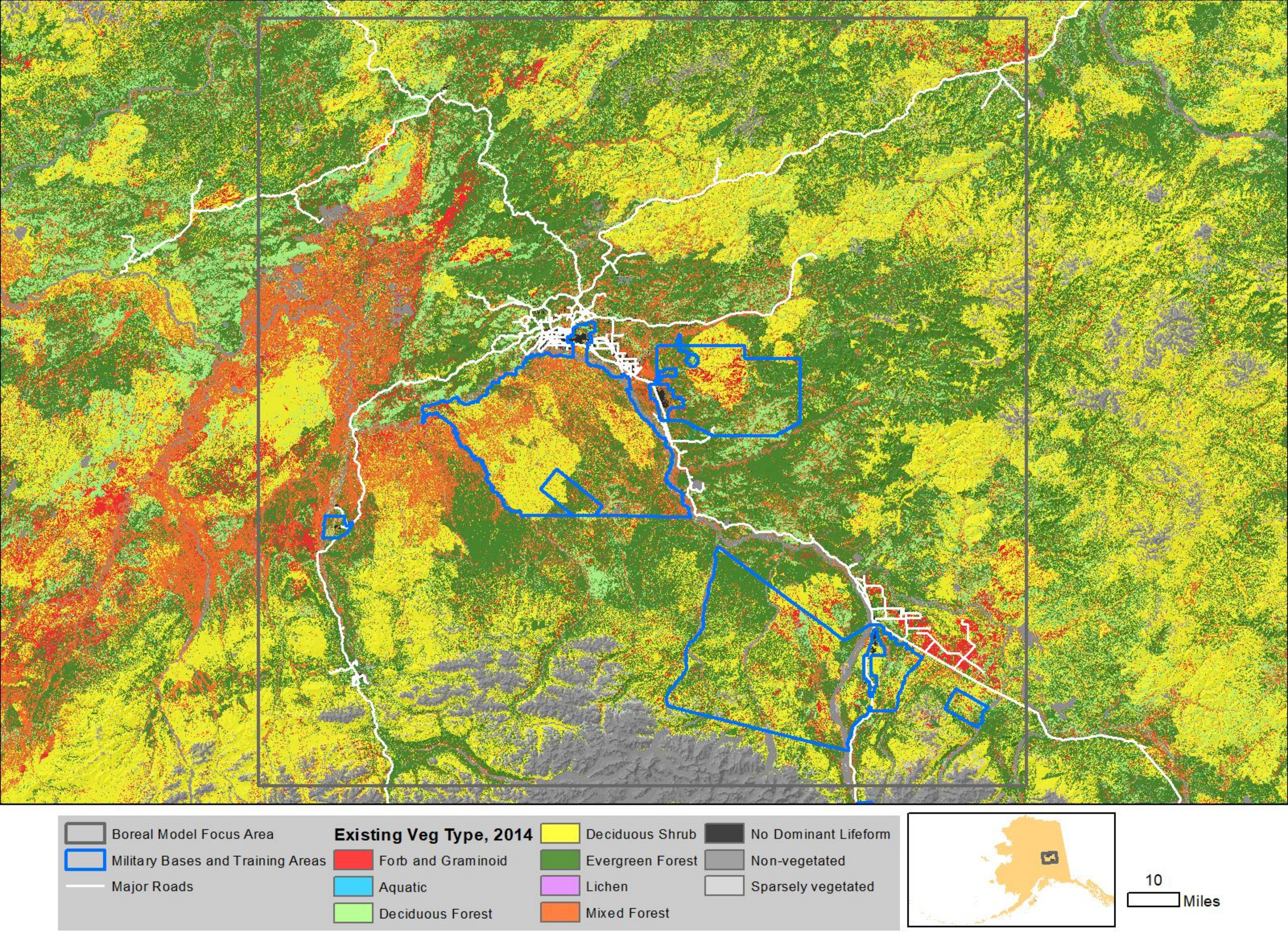


Task 2a: Remote sensing of canopy composition, density, burn severity

- *Overarching goal*: Map the trajectories of post-fire vegetation recovery & composition change related to burn severity
- *Image data*: Long-term NDVI from Landsat (30 m) & MODIS (250 m) supplemented with very high resolution (2-3m) imagery
- *Field data* calibration / validation: Canopy composition, cover, density, height *(in situ* and UAV)*;* depth of burning
- *Approach*:
  - Seasonal phenology time series to derive leaf habit (deciduous, evergreen).
  - Multi-year time series to map pre- and post-fire composition changes and trajectories

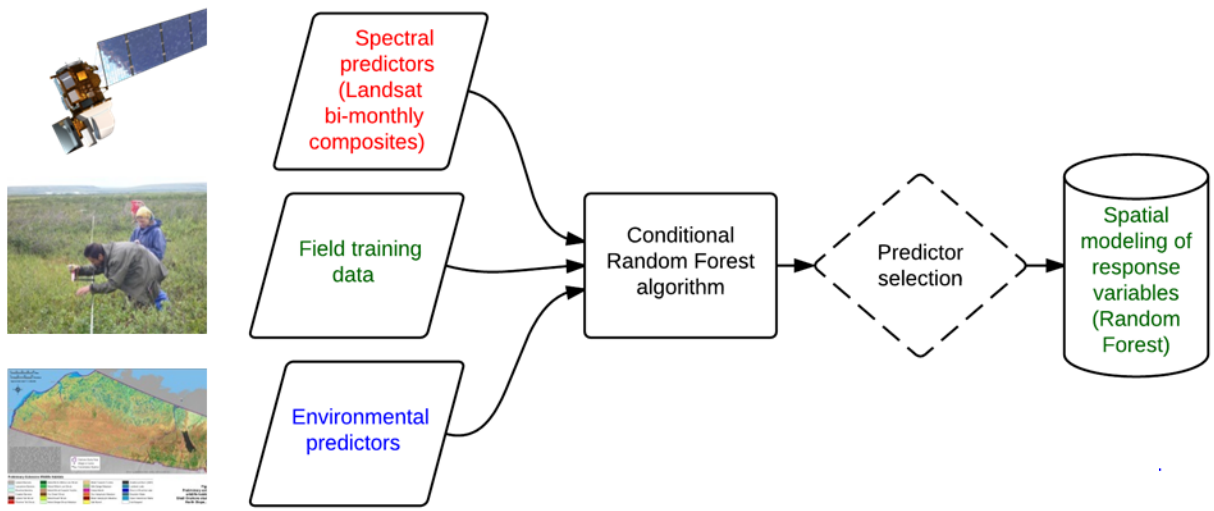

Fire History, 1940–2018 (Most Recent Fire Year)
Boreal Model Focus Area
Military Bases and Training Areas
Major Roads
1940s
1950s
1960s
1970s
1980s
1990s
2000s
2010s
10
Miles


Fire History and Severity, 1984–2018
Boreal Model Focus Area
Military Bases and Training Areas
Major Roads
1: Unburned or Low Severity
2: Low Burn Severity
3: Moderate Burn Severity
4: High Burn Severity
5: Increasing Greenness
6: Unknown (Clouds, Not Mapped, etc.)
10
Miles



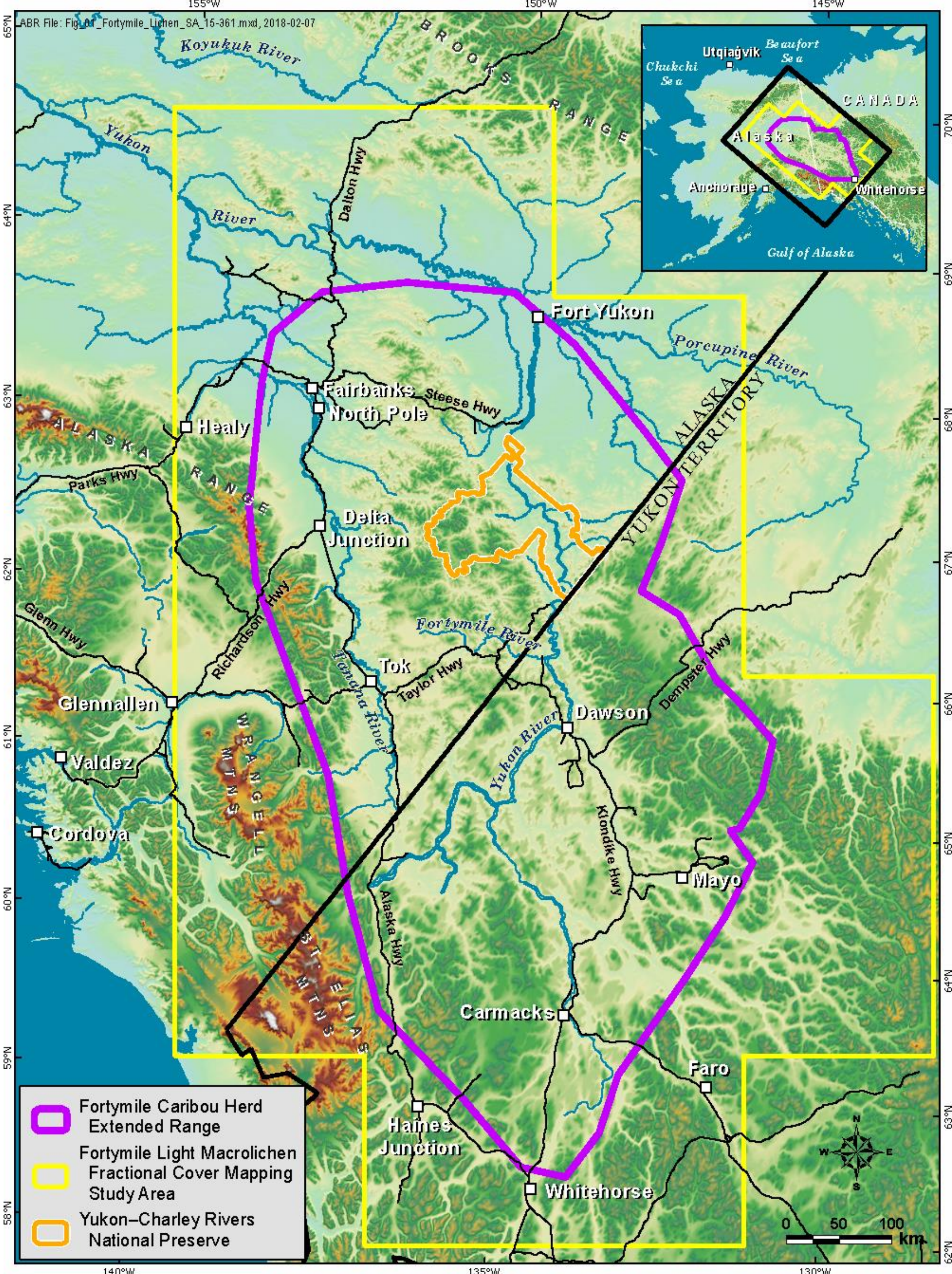
Boreal Model Focus Area
Military Bases and Training Areas
Major Roads
Existing Veg Type, 2014
Forb and Graminoid
Aquatic
Deciduous Forest
Deciduous Shrub
Evergreen Forest
Lichen
Mixed Forest
No Dominant Lifeform
Non-vegetated
Sparsely vegetated
10
Miles

Machine Learning Models (Random Forest)



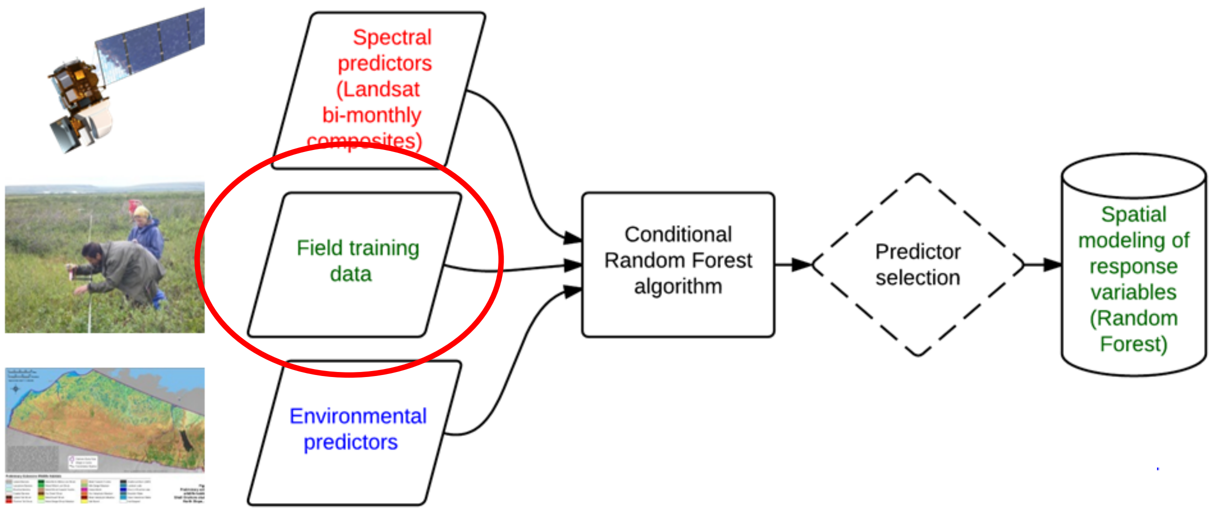
- Veg. Class
- Deciduous Fraction
- Burn Severity

Fortymile Forage Lichen Mapping Example

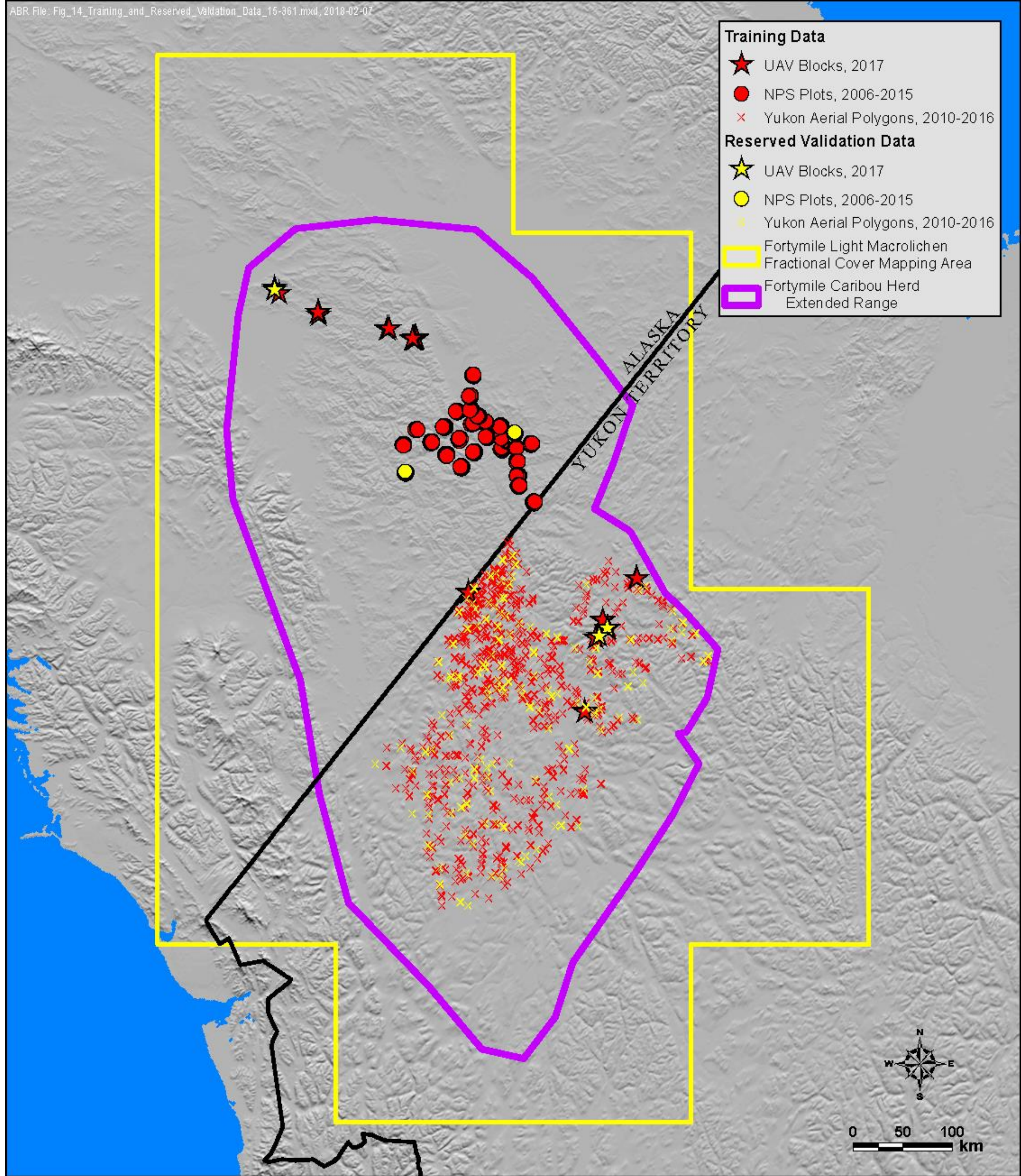


Machine Learning Models (Random Forest)

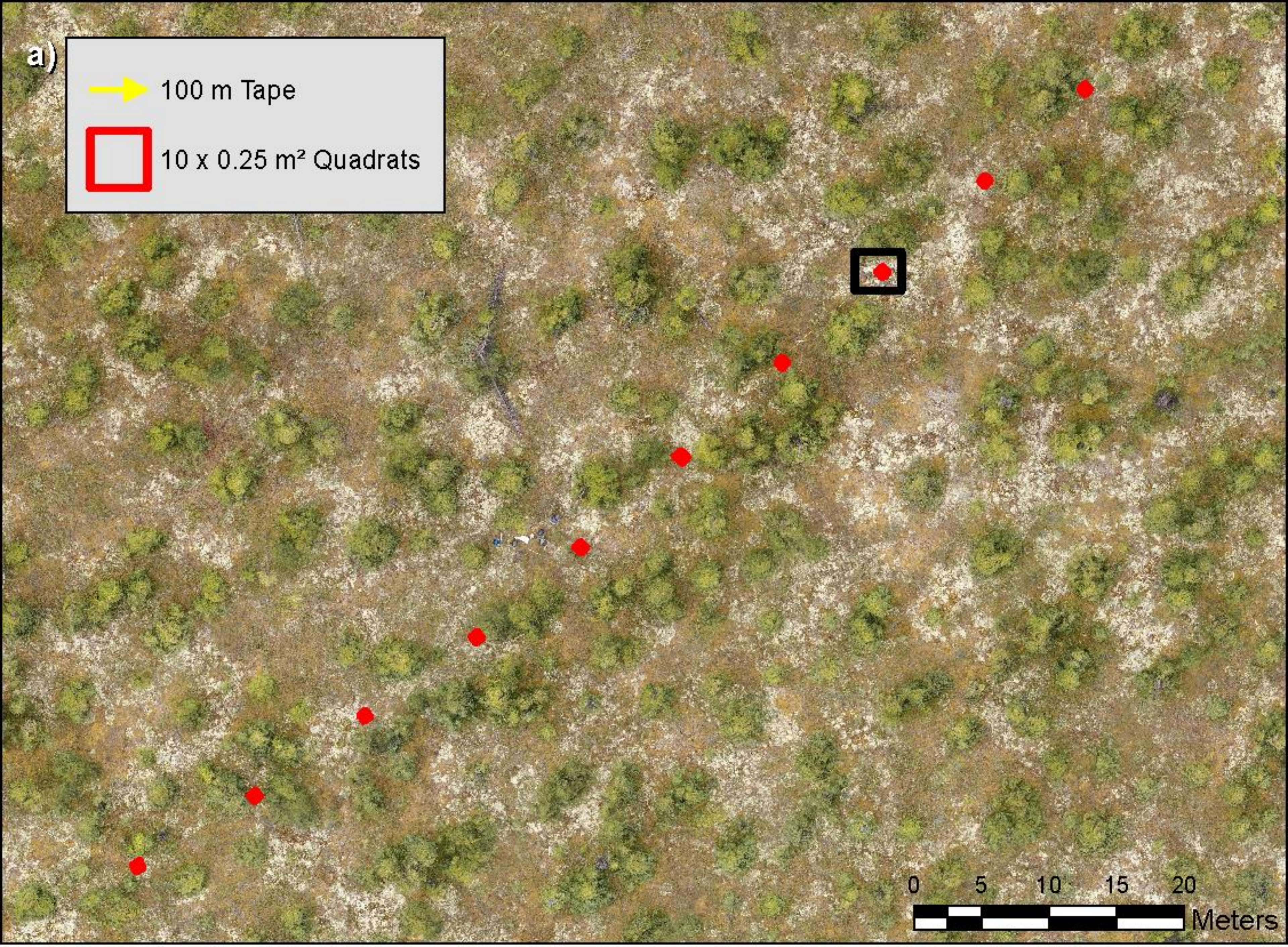
Fortymile Forage Lichen Mapping Example

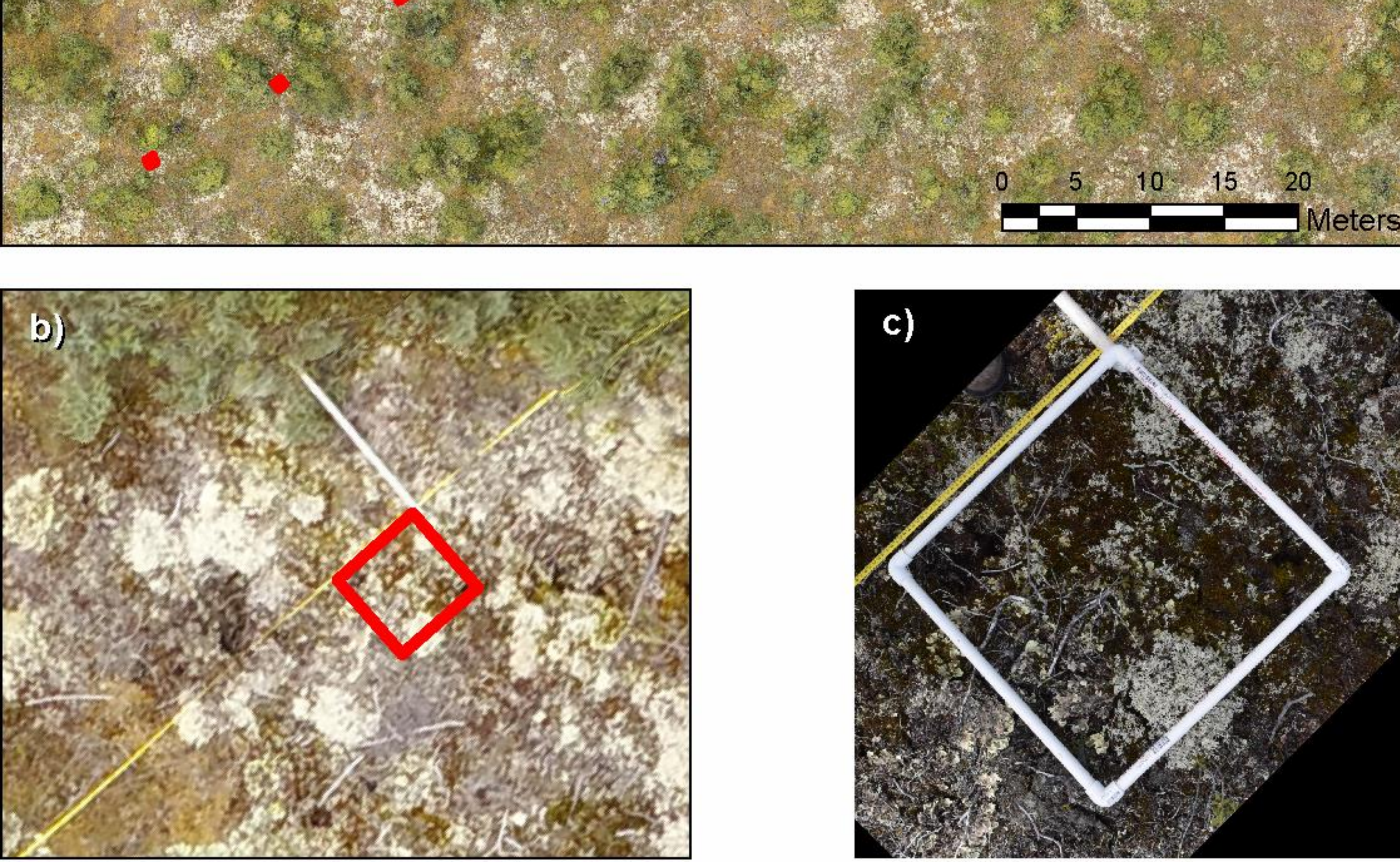


- Veg. Class
- Deciduous Fraction
- Burn Severity



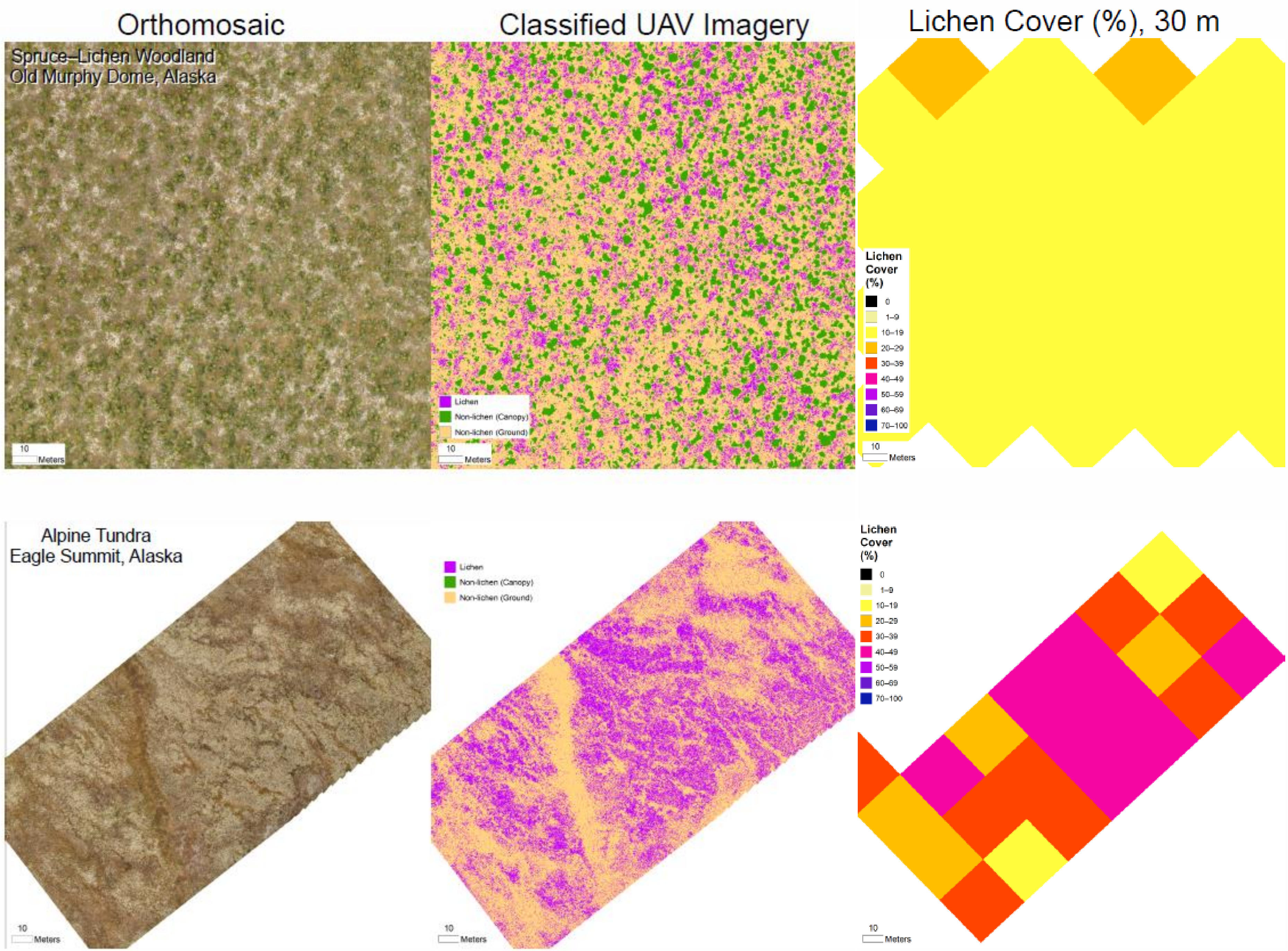
ABR File: Fig_14_Training_and_Reserved_Validation_Data_15-361.mxd, 2018-02-07
Training Data
UAV Blocks, 2017
NPS Plots, 2006-2015
Yukon Aerial Polygons, 2010-2016
Reserved Validation Data
UAV Blocks, 2017
NPS Plots, 2006-2015
Yukon Aerial Polygons, 2010-2016
Fortymile Light Macrolichen Fractional Cover Mapping Area
Fortymile Caribou Herd Extended Range
ALASKA
YUKON TERRITORY
N
S
W
E
0
50
100
km


a)
100 m Tape
10 x 0.25 m² Quadrats
0 5 10 15 20
Meters

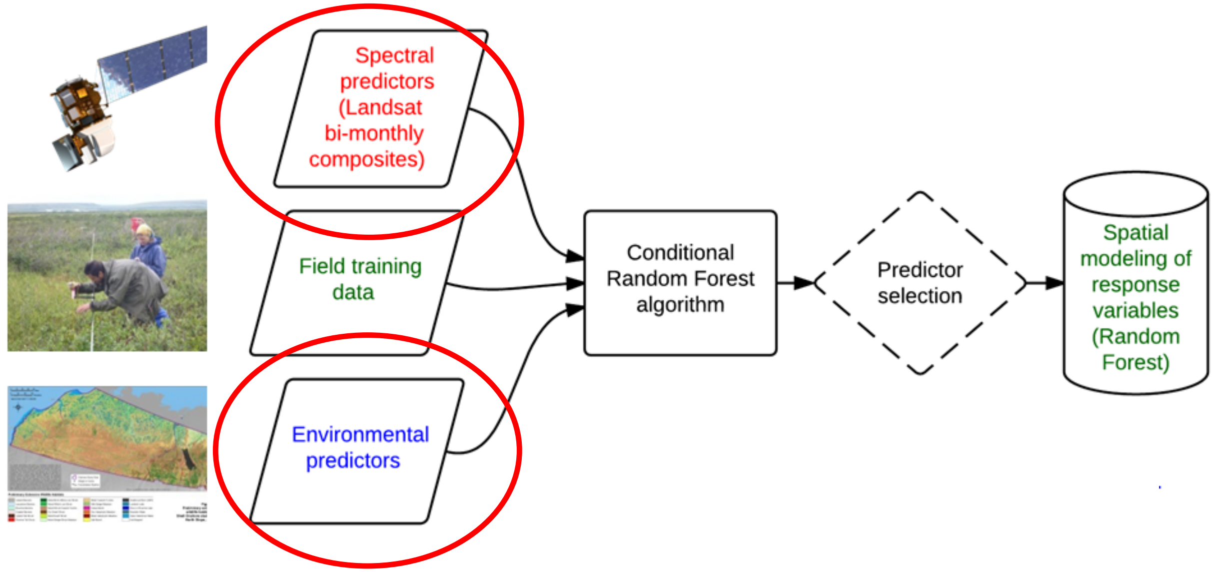


ABR File: Fig_04_UAV_Plot_Layout_2017_15-361.mxd, 2018-02-05

Figure 4. Layout of Unmanned Aerial Vehicle (UAV) lichen cover field plots, Alaska and Yukon Territory, 2017. a) Tape and quadrat layout at plot OMD_41_2017. Background imagery is 0.8 cm resolution color orthomosaic acquired with a UAV on 1 June 2017. b) Inset zoom of quadrat at 20 m along the tape. c) Vertical ground photo of the same quadrat acquired with a handheld camera.

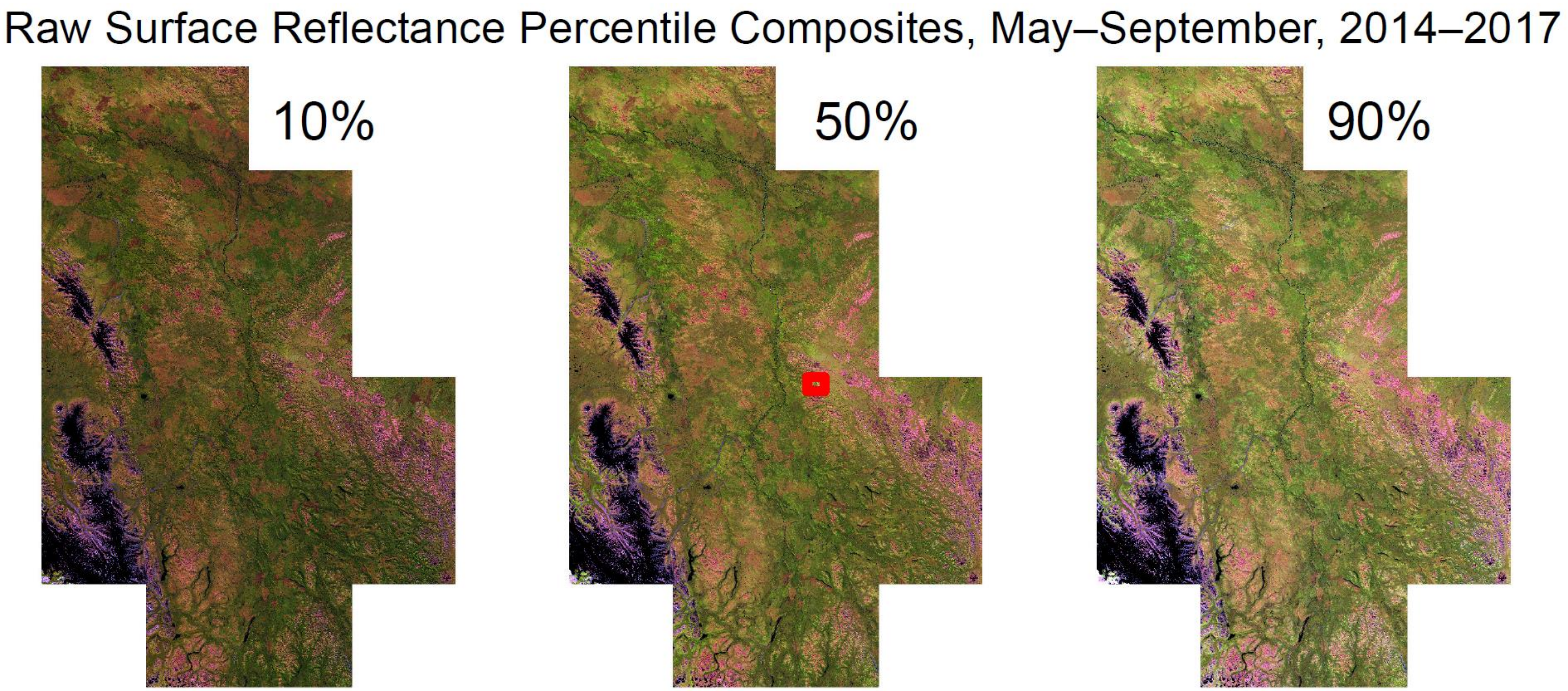

Orthomosaic
Classified UAV Imagery
Lichen Cover (%), 30 m
Spruce–Lichen Woodland
Old Murphy Dome, Alaska
Lichen
Non-lichen (Canopy)
Non-lichen (Ground)
Lichen Cover (%)
0
1–9
10–19
20–29
30–39
40–49
50–59
60–69
70–100
10
Meters
Alpine Tundra
Eagle Summit, Alaska

Machine Learning Models (Random Forest)
Fortymile Forage Lichen Mapping Example

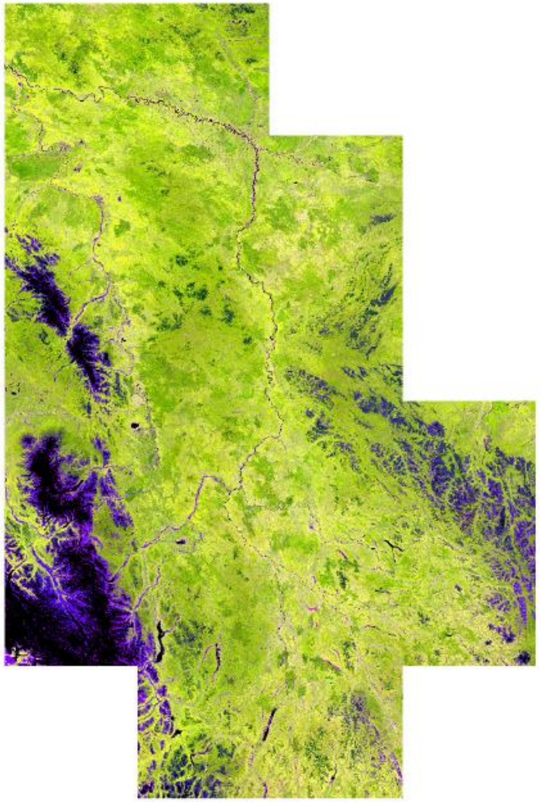


- Veg. Class
- Deciduous Fraction
- Burn Severity

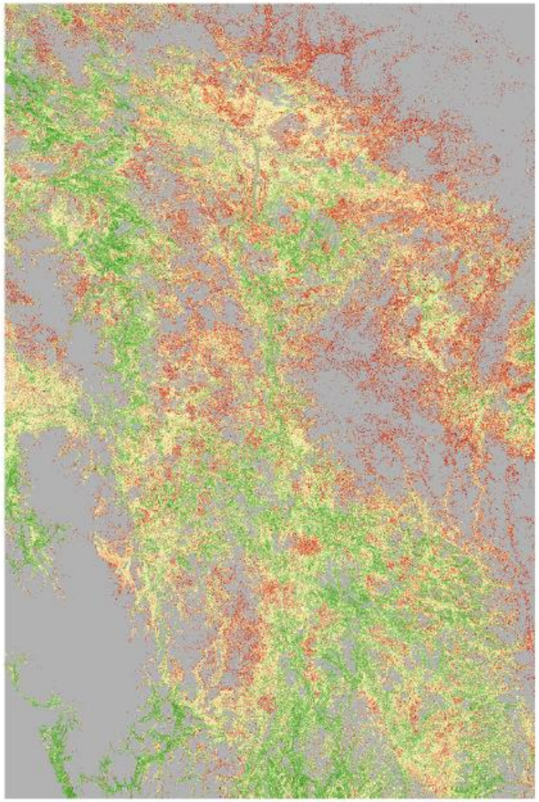
Spectral predictors: Landsat percentile composites (Fortymile Forage Lichen Example)



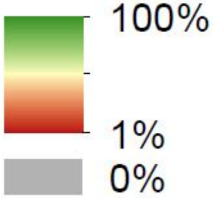
Additional Spectral and Environmental Predictors

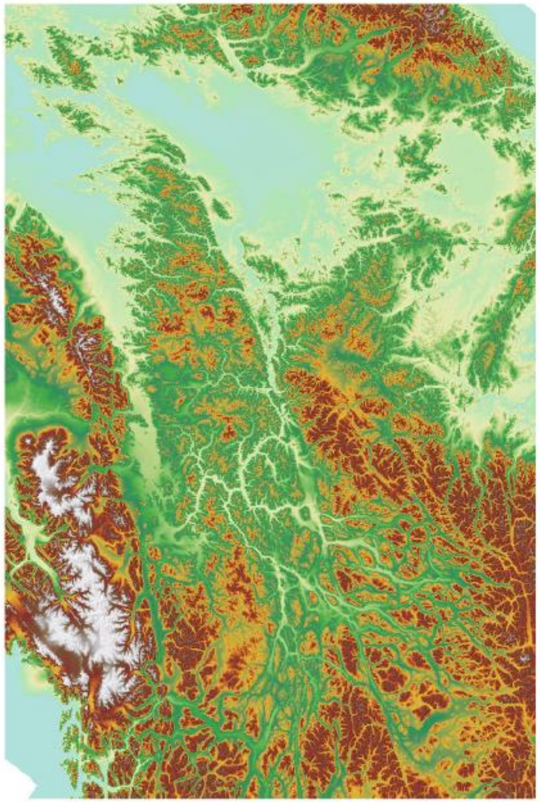


NDMI/NDVI/NDSI (50%)

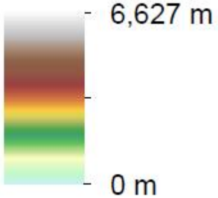


Tree Cover, 2016 (Hansen 2013)

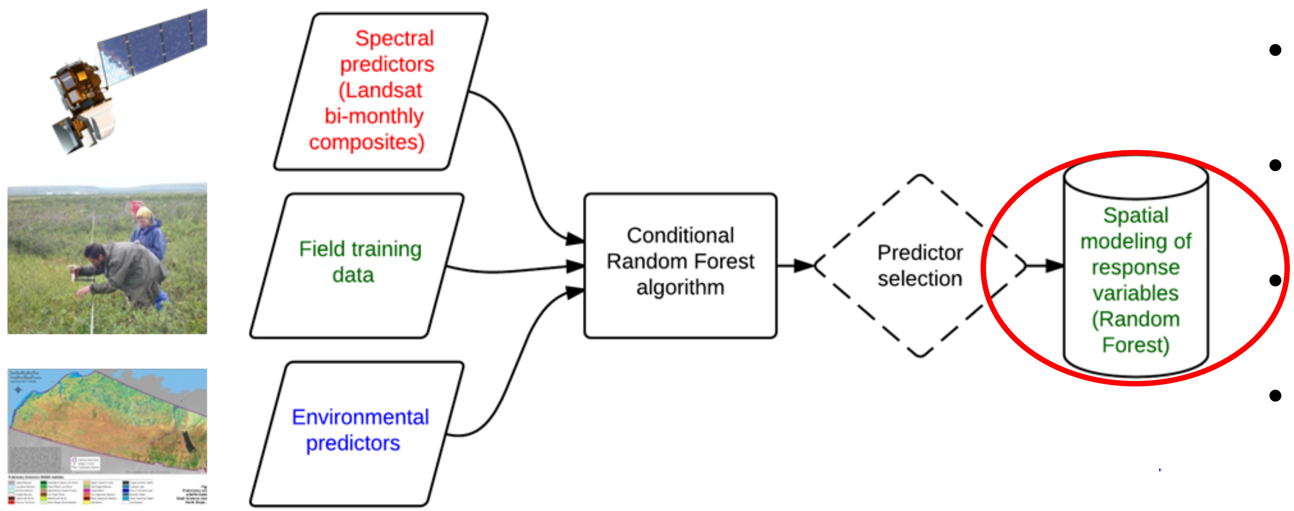




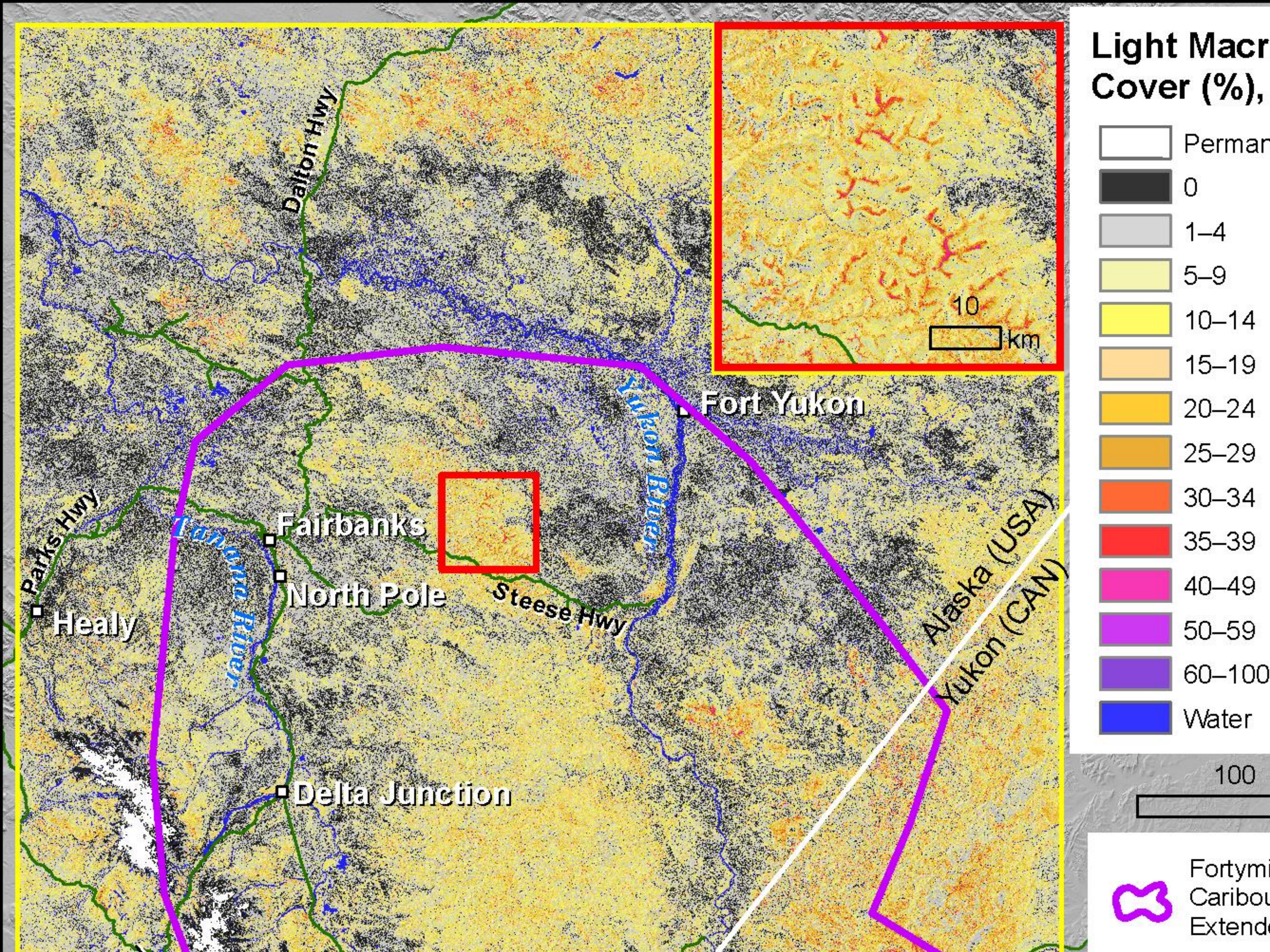
Elevation (m)



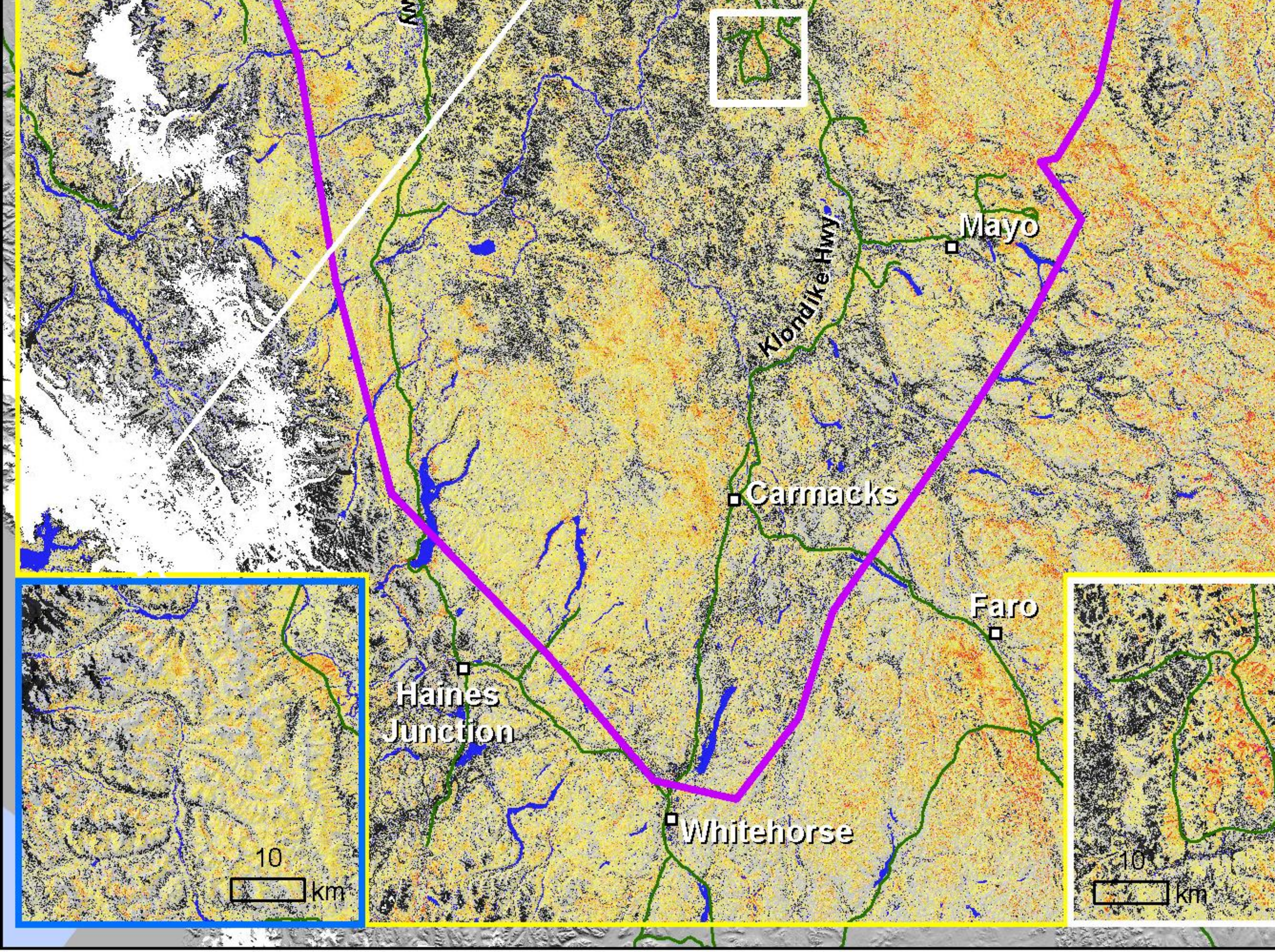
Machine Learning Models (Random Forest)
Fortymile Forage Lichen Mapping Example

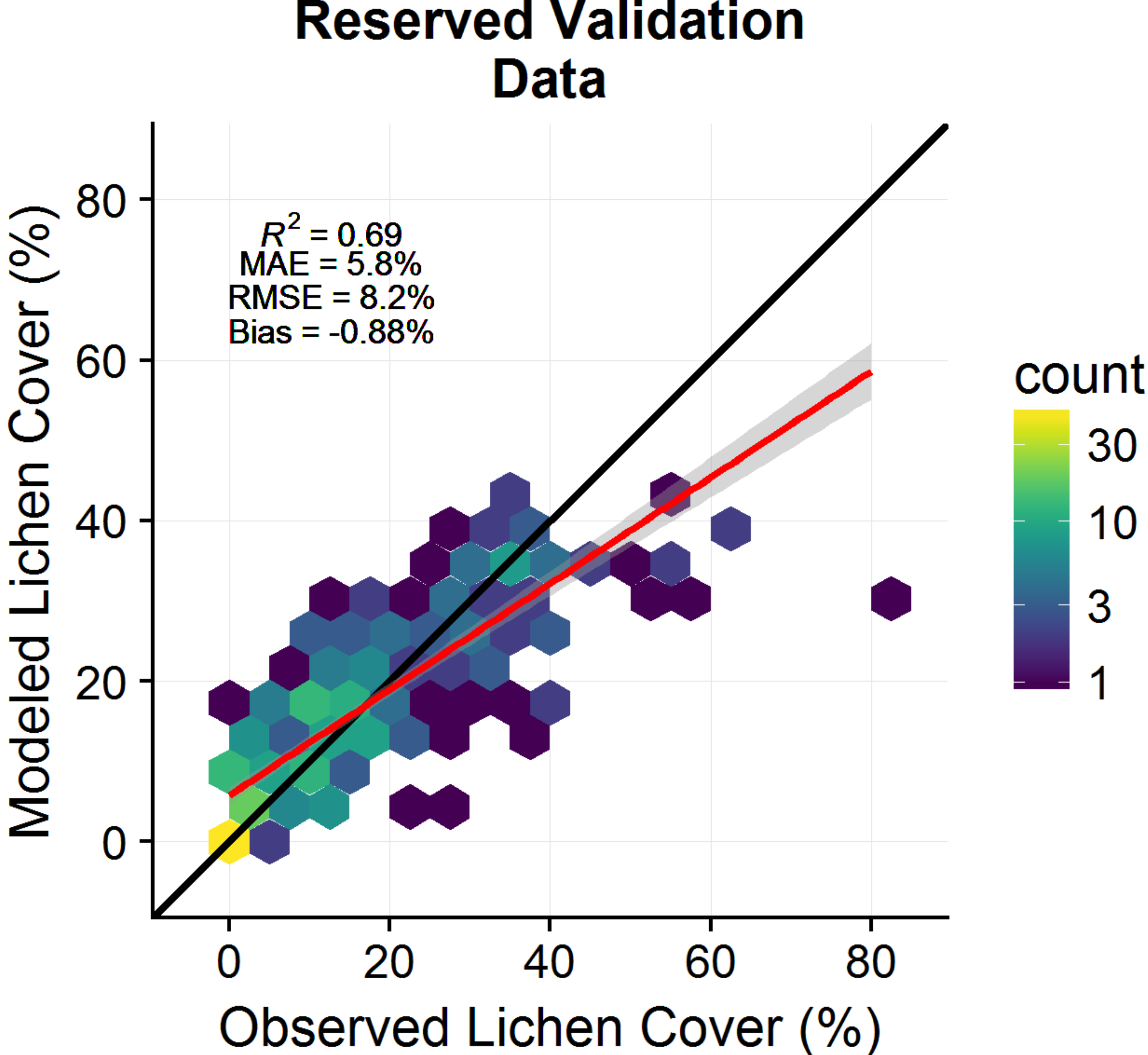


- %Lichen Cover
- Veg. Class
- Deciduous Fraction
- Burn Severity

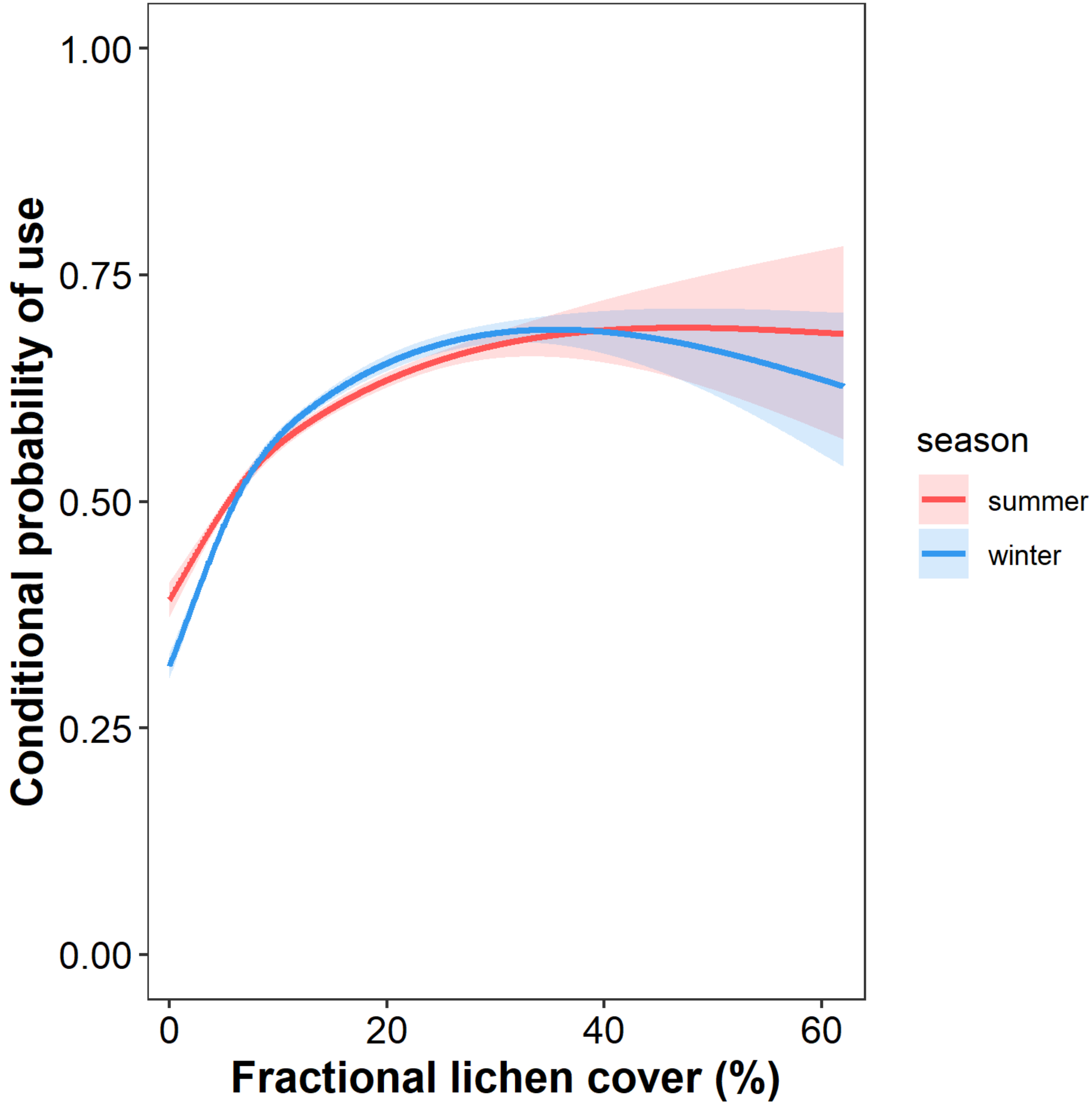


Light Macr
Cover (%),
Perman
0
1–4
5–9
10–14
15–19
20–24
25–29
30–34
35–39
40–49
50–59
60–100
Water
100
Fortymi
Caribou
Extende
Dalton Hwy
Fort Yukon
Yukon River
Fairbanks
North Pole
Tanana River
Steese Hwy
Parks Hwy
Healy
Delta Junction
Alaska (USA)
Yukon (CAN)
10
km

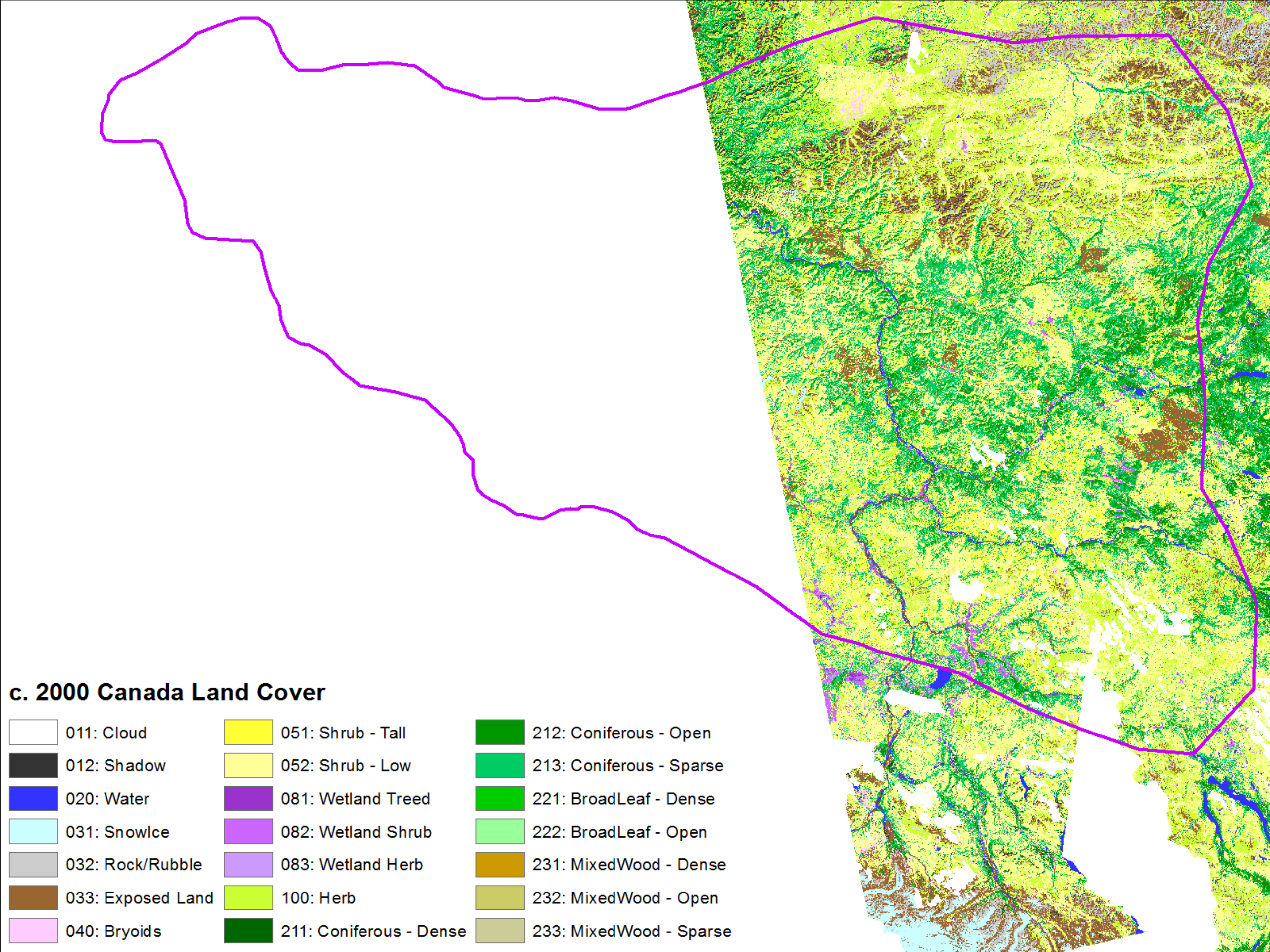

Klondike Hwy
Mayo
Carmacks
Faro
Haines
Junction
Whitehorse
10
km
10
km



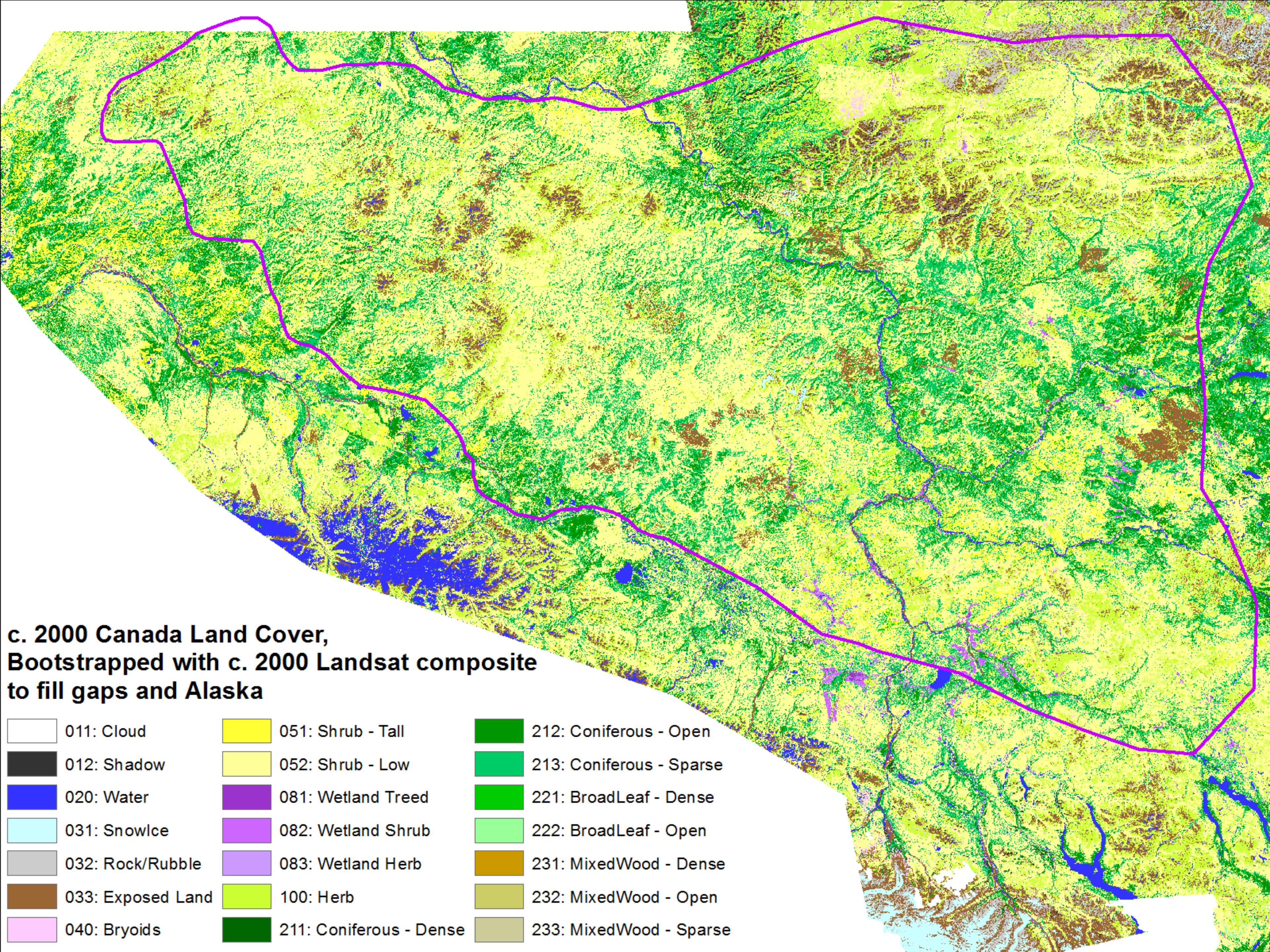
Reserved Validation Data
R^2 = 0.69
MAE = 5.8%
RMSE = 8.2%
Bias = -0.88%
Modeled Lichen Cover (%)
Observed Lichen Cover (%)
count
30
10
3
1
0
20
40
60
80

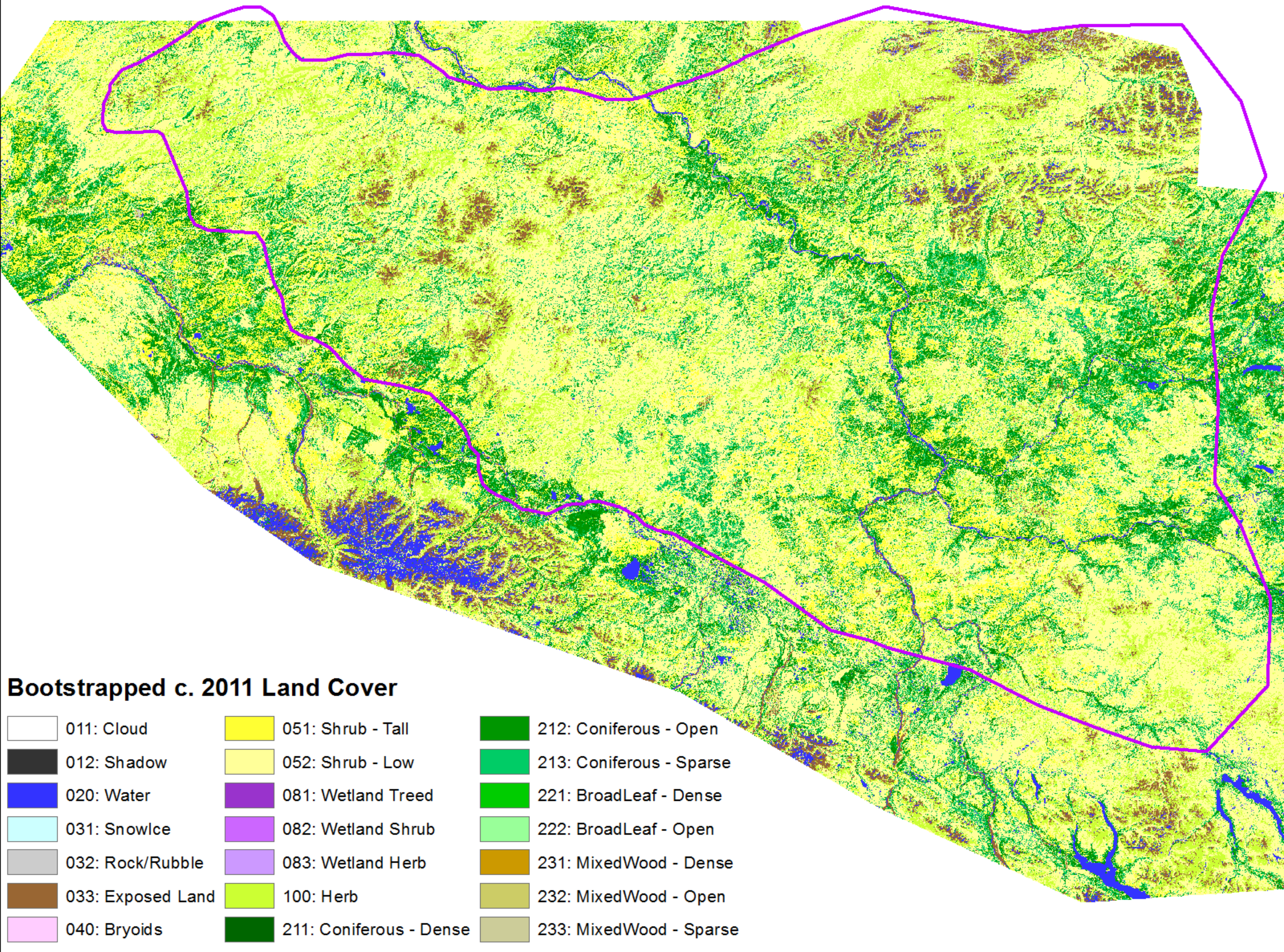


Conditional probability of use
1.00
0.75
0.50
0.25
0.00
0
20
40
60
Fractional lichen cover (%)
season
summer
winter

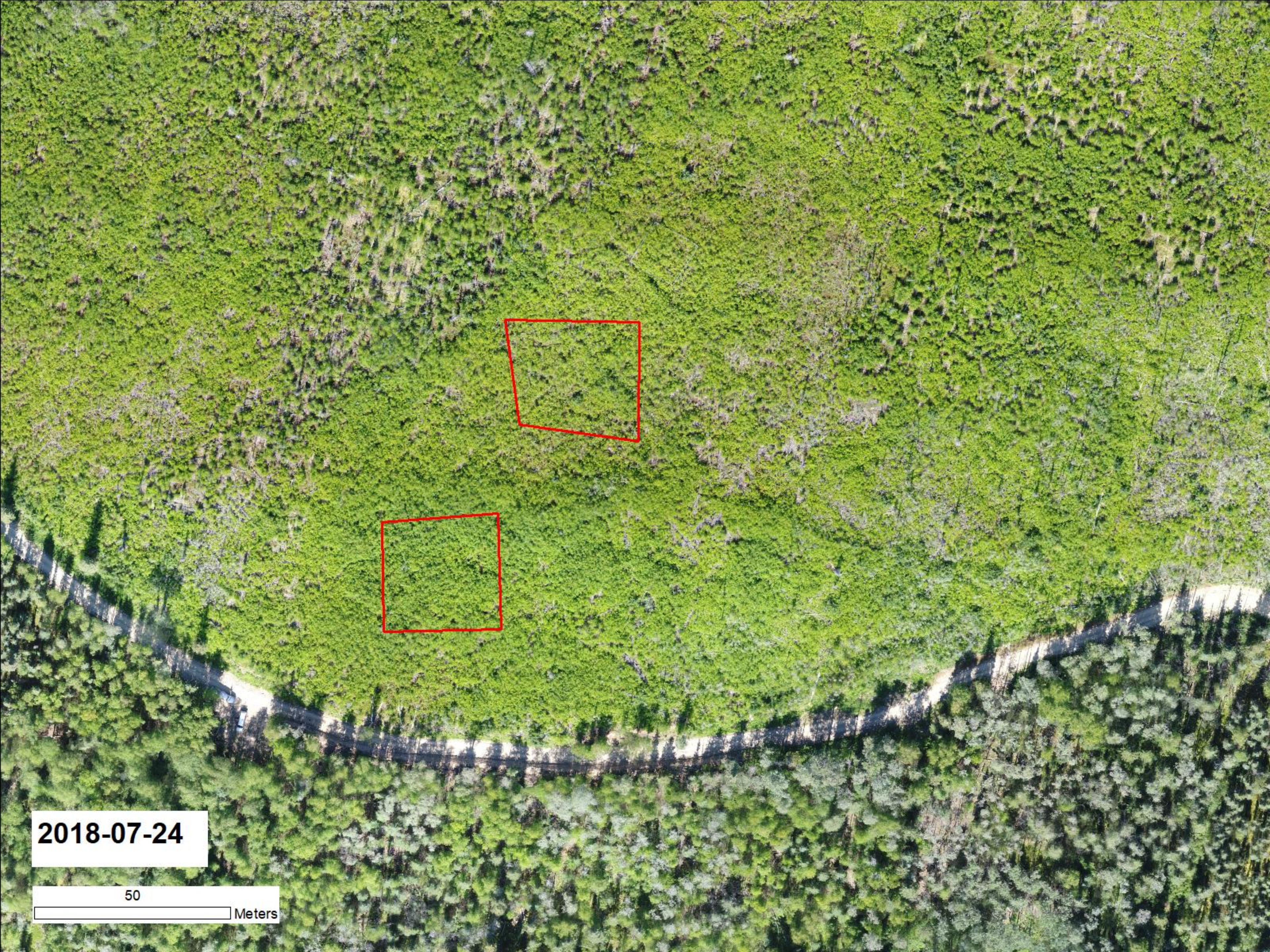


c. 2000 Canada Land Cover


c. 2000 Canada Land Cover,
Bootstrapped with c. 2000 Landsat composite
to fill gaps and Alaska
011: Cloud
012: Shadow
020: Water
031: SnowIce
032: Rock/Rubble
033: Exposed Land
040: Bryoids
051: Shrub - Tall
052: Shrub - Low
081: Wetland Treed
082: Wetland Shrub
083: Wetland Herb
100: Herb
211: Coniferous - Dense
212: Coniferous - Open
213: Coniferous - Sparse
221: BroadLeaf - Dense
222: BroadLeaf - Open
231: MixedWood - Dense
232: MixedWood - Open
233: MixedWood - Sparse



Bootstrapped c. 2011 Land Cover
011: Cloud
012: Shadow
020: Water
031: SnowIce
032: Rock/Rubble
033: Exposed Land
040: Bryoids
051: Shrub - Tall
052: Shrub - Low
081: Wetland Treed
082: Wetland Shrub
083: Wetland Herb
100: Herb
211: Coniferous - Dense
212: Coniferous - Open
213: Coniferous - Sparse
221: BroadLeaf - Dense
222: BroadLeaf - Open
231: MixedWood - Dense
232: MixedWood - Open
233: MixedWood - Sparse


2018-07-24
50
Meters


Spruce Seedlings
2018-05-16
50
Meters
Mature Spruce


2018-05-16
50
Meters


2018-07-24
50
Meters

Animation of 2018 Controlled Burn

Thank You

For more information:

Matt Macander

Senior Scientist

ABR, Inc.—Environmental Research & Services

Fairbanks, AK

(o) 907-455-6777 x112

(c) 907-347-7041